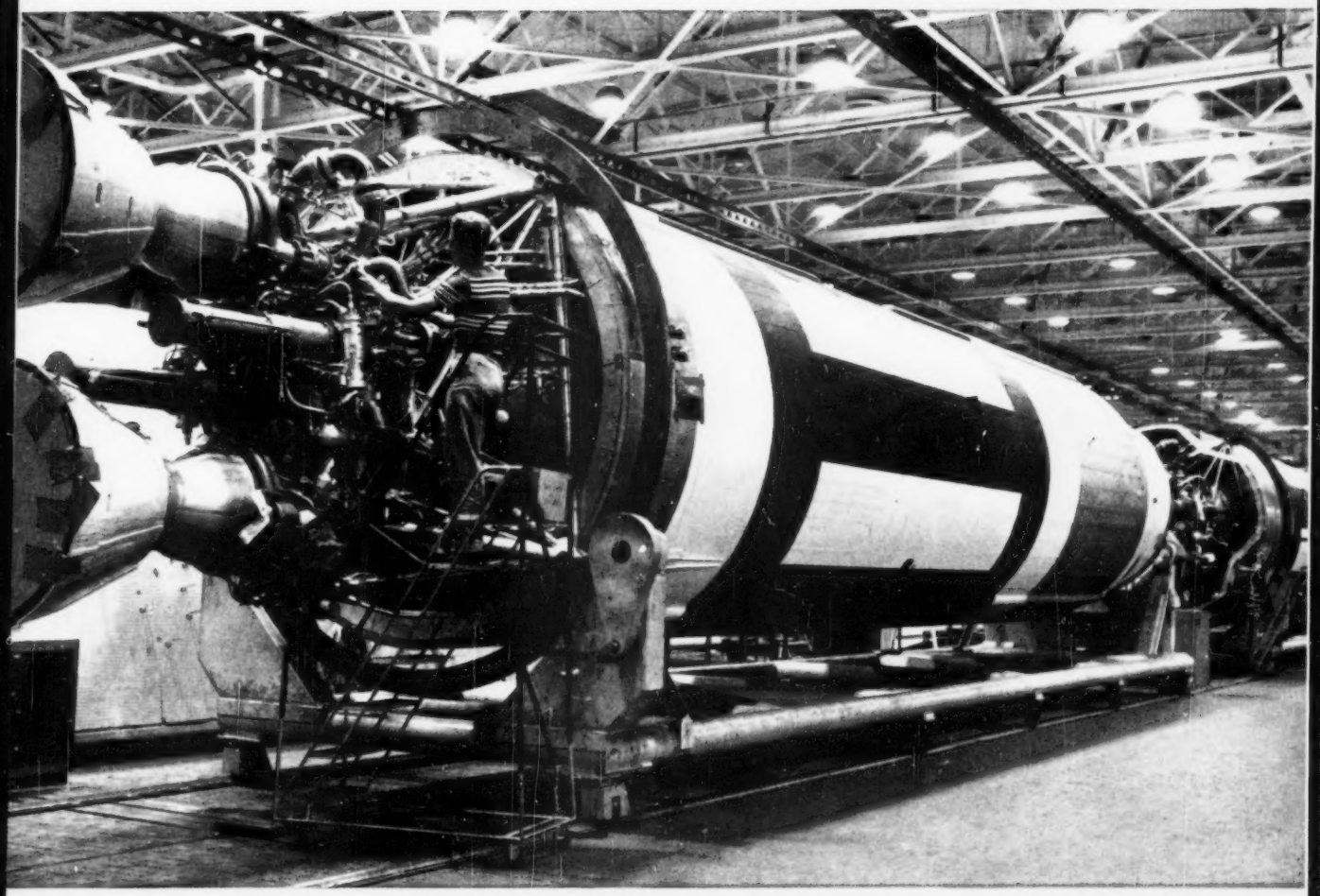

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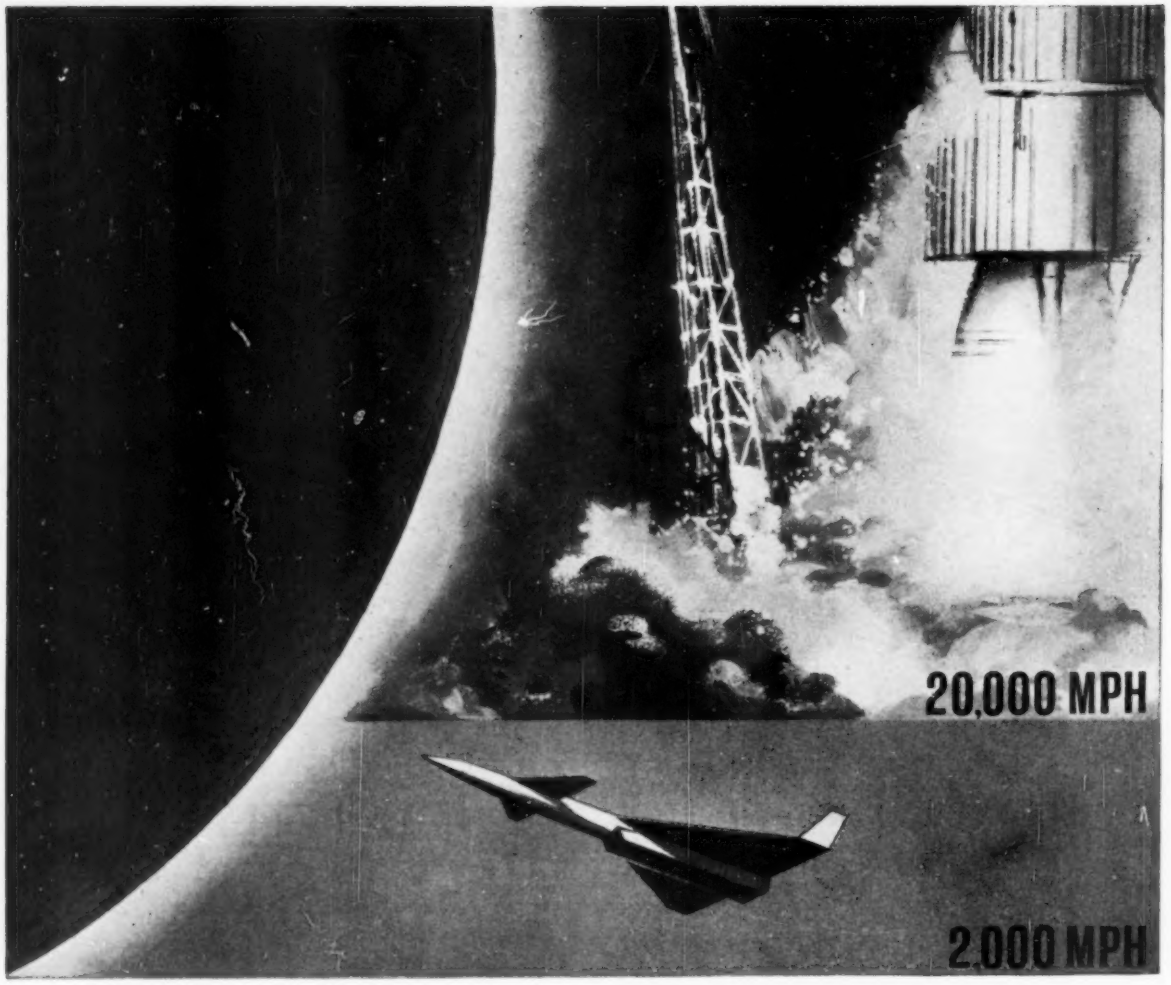

650 MPH

60 MPH

AEROSPACE - the new industry

Aerospace presents us with what is perhaps the most urgent industrialisation requirement of our time. Man-made satellites are required, virtually in quantity production, to operate as telecommunication relays and navigational aids. The development of the new techniques and materials is a familiar evolutionary process in the aircraft industry. It would be logical, therefore, to expect the aviation specialist to take the lead in this new and exciting venture.

HAWKER SIDDELEY AVIATION Kingston-upon-Thames, Surrey

SPACEFLIGHT

Volume III May 1961 Number 3

THE MAGAZINE OF AEROSPACE SCIENCE AND TECHNOLOGY

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COVER

Titan I first-stages in production at Martin's Denver factory in Colorado. The U.S.A.F.'s Dyna-Soar hypersonic glider will employ Titan II as a booster for sub-orbital test-flights beginning at Cape Canaveral in 1963.

The Martin Company

Man Into Space

The Russians cannot now be far from making an attempt to place their first astronaut in close-orbit around the Earth. At the time of writing, five experimental launchings have been made with 4½-ton spacecraft, the latest on 25 March when the dog Zvesdochka (Little Star) was safely recovered "at a predetermined point in the U.S.S.R."

Not all these attempts, of course, have been successful. In May last year, when a sputnik containing a "dummy astronaut" entered orbit, it was not recovered because an orientation fault caused the retro-rocket to fire in the wrong direction; instead of the vehicle following the prescribed re-entry path, it was propelled into a higher orbit.

Success attended the second experiment last August when two dogs, Strelka and Belka, with smaller animals, insects and plants, were safely recovered after spending some 24 hr. in orbit; according to *Tass*, they landed within 6¼ miles of the designated point in the Soviet Union. Not so fortunate, however, were the canine occupants of the next sputnik, launched in December, which perished when their spacecraft entered an "incorrect descent trajectory" and burned up in the atmosphere.

A change in the pattern of the experiments was evident in the launching on 9 March this year when the spacecraft was commanded to return after spending a much shorter time in orbit. On this occasion, only one dog was carried with the usual complement of smaller test animals, insects, etc., and all were safely recovered. The fifth experiment on 25 March repeated this procedure—again with success.

Thus, with three recoveries out of five, Russia may be approaching the stage where a decision will be made to substitute a manned capsule for that of the animals. Before this is done, however, it would be logical to expect one or two more consecutive successes with unmanned vehicles, and there is every possibility of these final qualifying tests being made within the next few weeks.

Meanwhile, in the United States, sub-orbital ballistic tests of the one-ton Mercury capsule are working up to the stage where one of the three astronauts selected may be given the opportunity of becoming a passenger in a Redstone-boosted capsule.

Appointment with Venus

Radio contact with the 1,420-lb. Russian Venus probe, launched on 12 February, was unfortunately lost after some 15 days. Considering the complexity of the probe itself, with its orientable solar cells and directional antenna, and the fact that its launching was carried out so accurately from a heavy sputnik orbiting the Earth the communications failure is all the more lamentable. The probe is due to rendezvous with Venus between 19-20 May and the last tracking information indicated that it would pass within 62,500 miles of the planet.

As the significance of the experiment clearly extends beyond the present mission, heralding further probing attempts to Venus—and Mars—we are arranging to include a full translation of the *Pravda* article describing the experiment in our next issue.

PRINTED IN GREAT BRITAIN

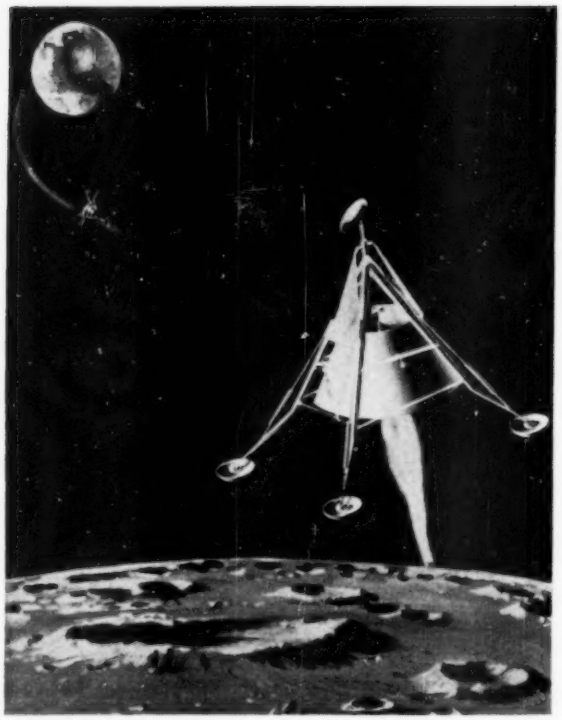
N.A.S.A. Looks Ahead*

A review of America's plans for extending space research and technology over the next 10 years.

By MORTON J. STOLLER†

Within the National Aeronautics and Space Administration, manned spaceflight, Earth satellite and sounding rocket programmes, and the development and operation of the world-wide satellite tracking and telemetry network, are the concern of the Goddard Space Flight Centre at Greenbelt, Maryland. The Jet Propulsion Laboratory is assigned the execution of unmanned lunar, planetary and interplanetary missions including tracking and data acquisition for lunar and deep space probes. The Wallops Station is used as a launching point for sounding rockets and vehicles up to and including the Scout in size. Space Flight Operations is that segment of our organization which is responsible for the world-wide complex of tracking, telemetry and communications networks. These networks include the Minitrack stations, the Baker-Nunn optical stations which are operated for N.A.S.A. by the Smithsonian Astrophysical Observatory, and the Project Mercury stations. These latter impose many special communication requirements because of the great importance of adequate real time data acquisition for the manned orbital flight mission. This office also co-ordinates the activities associated with the deep space network. This will eventually be comprised of three large data acquisition and tracking installations.

The space sciences phase of N.A.S.A.'s spaceflight programme is an outgrowth of the activity that started in 1945 when the first scientific experiments were flown on V-2 rockets captured at the end of World War II. This scientific activity was sponsored by the military services, and it eventually led to the establishment of highly competent groups of what we would now call "space scientists" at the Naval Research Laboratory, the Air Force Cambridge Research Centre, the Army Signal Corps Research and Development Laboratory, and the Army Ballistic Research Laboratory as well as at a number of university centres. Some of the scientists from the military establishments and others from the universities have joined the N.A.S.A. staff since its establishment, and have been instrumental in developing N.A.S.A.'s space science programme. Our programme of scientific studies in space has three comprehensive objectives. These are: (1) to investigate the energy transfer relations between the Sun and the Earth, or to study what are commonly known as solar-terrestrial relations, (2) to probe the origin and fundamental workings of the solar system and the Universe, and (3) to search for the origin and distribution of life within our solar system. That portion of the scientific programme which can be accomplished by sounding rockets, near-Earth probes and satellites, is under the cognizance of my Office. Those elements of the programme which are concerned with lunar, interplanetary, and planetary investigations are directed by the Office of Lunar and Planetary Programmes. Within the Office of Satellite and Sounding Rocket Programmes we are engaged in studies in a number of scientific disciplines.



Artist's impression of the N.A.S.A. soft-landing Moon-probe Surveyor (see also page 85).

All illustrations National Aeronautics and Space Administration

**The abridged text of a lecture given before a meeting of the British Interplanetary Society in London on 1st Oct., 1960.*

†Assisiant Director, Satellite and Sounding Rocket Programmes, N.A.S.A.

The general nature of the experiments which can be conducted with sounding rockets is fairly well known. We generally do not expect to recover either the instrumentation or the vehicle, but we depend instead on telemetry for data recovery. There are some recovery techniques available, however, and occasionally we make use of them to recover either records or specimens from sounding rocket flights. At the moment, we are engaged in two operations requiring payload recovery. One of these is a solar flare programme in which we are attempting to launch rockets upon receipt of information of enhanced solar activity. These rockets carry energetic particle detectors and nuclear emulsions, and we expect that the analysis of these emulsions will enable us to trace in some detail the change in particle population in the upper atmosphere as a result of the solar flare. The second of these programmes also carries nuclear emulsions, in this case into the lower regions of the Van Allen belt. Low-altitude rocket operations can generally be conducted on a dry land test range for the recovery operation, but if we use high-altitude rocket systems, which ascend up to 800 to 1000 miles, the problems of dispersion and required range size make it imperative that we use water-recovery techniques.

Our satellite programme is, of course, intended to support studies in the same areas of science that we have already mentioned. With the exception of the first Vanguard satellite, which has been the subject of a number of studies resulting in new discoveries in geodesy and data on the upper atmosphere, the only scientific satellite which is still transmitting data is Explorer VII. This unit actually managed to bring together all those experiments which had not yet had a chance for successful flight in the U.S.-I.G.Y. programme. With its successful launching in October, 1959, all the I.G.Y. satellite experiments finally reached orbit. We are now within just a few weeks* of a year's flight for Explorer VII. There was installed in it a timing device to cut off the radio transmission at the end of a nominal period of 1 year. This was done so as to prevent its transmissions continually cluttering up the radio frequency channels. We will soon learn whether the timer will function properly after a year in space. (*In fact it did not.—Ed.*)

We have had some difficulties in flight with Explorer VII as one of the transistors started to shift its characteristics with temperature. As the satellite encounters greater or lesser periods of darkness, the resultant temperature variations have resulted in one of the telemetry channels failing to function properly and in recent weeks we have had trouble with the telemetry transmitter. In the main, however, it has been possible to recover data successfully and consistently from the thermal radiation experiment, the Geiger counters and the ion chamber unit.

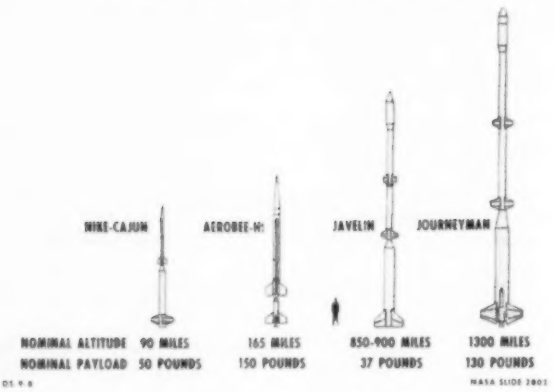
A number of satellites of the same general design philosophy as Explorer VII are due to be flown in the next few years. That is, they are of relatively light weight, somewhat between 80 and 300 lb. They may contain experiments grouped for convenience simply because they will all fit together without interference, or they may be grouped so as to make an interdisciplinary study. Some of these satellites concentrate on a single area of study, particularly where the weight limitation requires that the complete satellite be so assigned in order to conduct an effective experiment. These satellites will be flown on Juno II's, Deltas and Thor-Agenas. They cover such experimental areas as gamma-ray astronomy, direct measurements of the ionosphere, propagation measurements through the ionosphere, measurement of the radiation belts and measurement of the atmospheric structure.

Solar Satellite

The most complex of the satellites that we plan to launch in the near future is the Orbiting Solar Observatory. It consists of a large lower unit, which we call the wheel, an arm and a solar panel. Three weights which fold out increase the moment of inertia of the wheel. The arm and the solar panel are mounted on the axle of the wheel. The wheel rotates continuously and serves by its gyroscopic action to stabilize the satellite in space. There is a pointing control device which is used to rotate the satellite to such a position that the plane of the wheel cuts through the Sun. The arm is then allowed to rotate on the axle until it points at the Sun. Since the solar panel is at right-angles to the arm, the solar panel is then facing the Sun and is in a position to recharge the storage cells within the wheel. In the first version of this satellite the arm will contain two solar ultra-violet spectrographs. The wheel contains a number of experiments in solar physics and geophysics which do not need the solar pointing capability. Should the system tend to drift off the solar disc, optical pointing detectors will cause a set of gas jets at the top of the solar panel to operate. The jets are supplied from a gas bottle in the hub of the wheel. By pulsing these jets, it is possible to precess the wheel and arm back into solar alignment. A fine pointing control for the arm is also provided.

**When the lecture was originally presented on 1 Oct., 1960.*

TYPICAL SOUNDING ROCKETS


NIKE-CAJUN
AEROBEE-H
JAVELIN
JOURNEYMAN
NOMINAL ALTITUDE 90 MILES 165 MILES 850-900 MILES 1300 MILES
NOMINAL PAYLOAD 50 POUNDS 150 POUNDS 37 POUNDS 130 POUNDS

We hope to use the basic structure of this observatory, with its pointing controls and dual telemetry included, several times in the course of the next few years. The experiments will change but the wheel and arm structure and the pointing controls will remain the same.

In this respect, the satellite spacecraft programme is being directed in a manner similar to that of the launching vehicle programme; that is, we are attempting to reduce the number and varieties of shape and size of our satellites. We believe that we can reutilize a given spacecraft a number of times before undertaking a major re-design. In this way, we expect to save a great deal of engineering effort as well as achieving an increase in system reliability.

The natural next step in this repetitive use programme is the spacecraft we have designated as the Orbiting Geophysical Observatory. For this, we envisage a central body which contains the instruments, the common telemetry, the command receiving system, and all the other devices (we call them housekeeping devices) needed to adjust and report on the internal conditions of the satellite. On the outside are attached the large solar panels, and several booms or extendable arms, to which those experimental sensors which have to be isolated from the main body or mass of the satellite are attached. We expect to launch these geophysical observatories into both near-Earth almost circular polar orbits, and in highly eccentric orbits out to some 60,000 miles or more. We hope to use the same spacecraft structure repetitively for both near- and far-Earth orbits. The Thor-Agena is an adequate vehicle to handle the near-Earth polar orbit with a spacecraft weight of about 1000 lb. The Atlas-Agena would be required for the highly eccentric orbit and the spacecraft weight would have to be somewhat less. There is to be a potential for growth in weight in the payload design and it is expected that the Centaur vehicles will eventually be used to launch the same spacecraft, with the greater weight, into the high apogee orbit.

The scientific satellite programme will also make use over a period of years of an Orbiting Astronomical Observatory. This will be far more complex than either the solar or the geophysical observatories. It will have provisions for precise pointing control and relatively elaborate data handling devices. The central core of this observatory spacecraft will be an interchangeable instrument container which will enable us to prepare several different sets of experiments for flight in the basic structure. The capacity of the system will be such that a mirror up to 36 in. diameter can be installed in the central element. The experiments we are planning for this vehicle include an ultra-violet sky-mapping survey, multi-colour ultra-violet photometry of stars, low dispersion stellar ultra-violet spectroscopic studies, absolute ultra-violet spectrophotometry of both stars and extended emission regions, and finally a very high resolution ultra-violet spectrometer will be used to examine in detail the absorption effects of the interstellar medium. The last of these experiments will require extremely high precision pointing stability and for this reason provision has been made to take advantage of the signals from the optics that the experimenter will provide, to drive the sensors which will control the direction of the optical axis of the observatory. Under these conditions we hope the unit will be stabilized to a fraction of a second of arc. There will be a command control system and an internal stored programme device which will make it possible for the experimenter to load the satellite-borne memory of the programmer with instructions to point to successive stars in the course of an orbit and to store the data collected in the course of that orbit in a separate memory. When the satellite once again reappears over the master control and telemetry station the memory devices will be read out to the ground receiving equipment and the programming unit will be reset for the next cycle of operation. Should there be a failure of these devices provision has been made for direct real time data read out and control.

We expect to launch an average of about one hundred sounding rockets a year by 1962, and to launch six to nine small satellites a year for the present, this number becoming about six per year by 1963. The large satellites class includes the larger solar, geophysical and astronomical observatories. About four launchings of this class per year by 1964 are being planned.

The second major area of the space science portion of our programme is the lunar and planetary section. In 1962, three Ranger vehicles are planned for flights to impact the surface of the Moon. These will be followed by the soft-landing mission. "Surveyor" and "Prospector" have been chosen as designations for spacecraft in this series. It is possible that a more complete investigation of the lunar surface characteristics by the the use of an advanced lunar orbiter may precede surface exploration with a mobile vehicle.

It would be expected that the instrumented lunar programme would eventually evolve into the manned programme of lunar exploration, although it is likely that unmanned payloads will be continued at some level for an indefinite period.

In the planetary programme, "Mariner" spacecraft are planned for Mars and Venus fly-bys at the first practical opportunity. The interplanetary environment will be studied en route. "Voyager" spacecraft, using the Saturn vehicle, are being considered for advanced planetary orbiters. Planetary landing vehicles, flights for solar studies, and investigations out of the plane of the ecliptic will have to await the development of vehicles with adequate capabilities. Development and study for these missions will continue over a period of years.

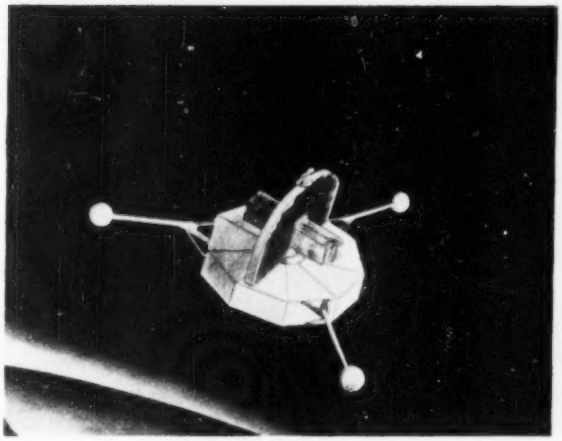
Ranger and Mariner.

Spacecraft are being planned for use on lunar, planetary and interplanetary missions with gross weights varying from 600 to 1200 lb. One particular variant will be used on interplanetary missions launched with Atlas-Agena vehicles in an early phase of Project Ranger. Although the primary purpose of these flights is to test the spacecraft and component developments, a set of seven scientific experiments has been included. A version differing primarily in the instrumentation carried will, we hope, be used on the early planetary missions to Mars and Venus under Project Mariner.

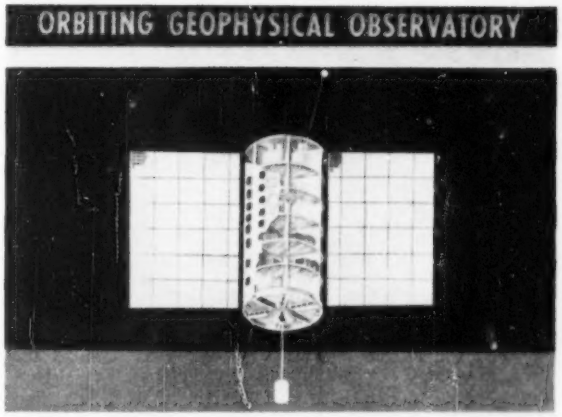
The lunar impact missions, which conclude Project Ranger, will also use a modified version of this spacecraft. This version is being designed to carry a survivable capsule containing a seismometer as the primary experiment. The spacecraft is being developed by the Jet Propulsion Laboratory, while the capsule is under contract to the Aeronutronics Division of Ford Motor Company. The Ranger flight plan is shown on this page. During the early stages of the flight, the spacecraft is designed to maintain three-axis attitude control with its antenna pointing toward the Earth and its solar panels toward the Sun. Radio tracking will reveal any necessary course corrections, which the spacecraft will then make on command by orienting itself for a mid-course rocket firing and then reorienting itself with its principal axis toward the Sun for travel through cislunar space. As the spacecraft approaches the lunar surface, it will orient itself on command along the vertical descent path and will begin to take high resolution television pictures and will activate a gamma-ray spectrometer. At the lowest possible altitude the survivable capsule will be slowed by retrorocket for a rough but safe landing. The main spacecraft will be destroyed on impact.

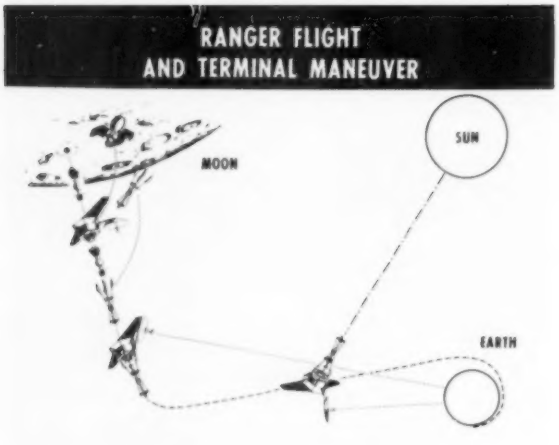
The two spacecraft types just described are well along in development, as are their scientific payloads, with the exception of some of the planetary probe instrumentation. The following spacecraft for the more advanced missions are still in the planning stage.

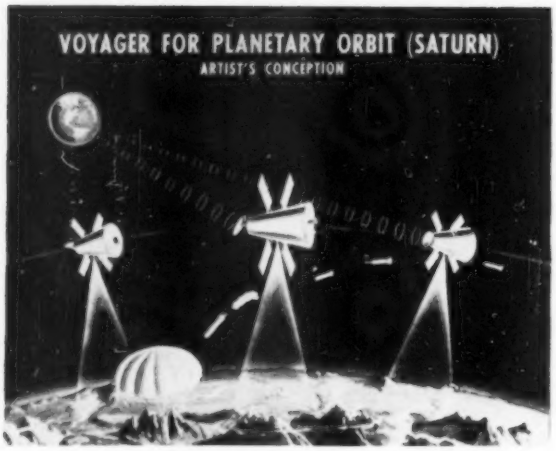
The next spacecraft to be undertaken as part of the lunar and planetary programme is Surveyor. It is designed for the lunar soft-landing mission using a Centaur launch vehicle. Intended to deposit a moderately heavy (100 to 300 lb.) scientific payload on the lunar surface, it is designed to test for the existence of local fields or atmosphere, and would also examine the



Orbiting Solar Observatory







surface and subsurface characteristics with a variety of instruments, including television, spectrometer, seismometer, magnetometer, and others.

Mobile Surface Probe.

The lunar soft-landing spacecraft for Saturn (Prospector) is currently under study by the Jet Propulsion Laboratory, and by the Marshall Space Flight Centre for J.P.L. As now envisaged, the Prospector spacecraft would consist of a soft-landing "truck" plus several alternative payloads. This mobile laboratory would have first priority as a Prospector payload. It would be capable of exploring throughout a radius of perhaps 50 miles, terrain permitting, and would obtain orders of magnitude more data than could be obtained with Centaur stationary spacecraft. It is anticipated that the mobile vehicle would be used in areas of particular interest as highlighted by previous flights with Centaur.

The Voyager series is conceived as being launched with the Saturn vehicle to orbit Mars and Venus. The spacecraft would be designed to eject an instrumented capsule for atmospheric entry and perhaps landing. Data from the capsule could be stored and relayed by the mother craft or, technology permitting, could be received directly on Earth.

Satellite Meteorology.

N.A.S.A.'s spaceflight applications programme has two basic facets at present. One is meteorology and the other is communications. The success of the Tiros I and II meteorological satellites is well known. The possibilities of expanding the satellite cloud cover and infra-red survey programme into an operational meteorological programme have been already discussed by others. Beyond Tiros, N.A.S.A. plans to develop the Nimbus series of meteorological satellites. These are expected to weigh 600–700 lb. and will be put into orbit with Thor-Agena B launch vehicles. They will have a stabilization system to keep the cameras and other sensors pointed earthward at all times. The sensors will include TV cameras, passive and scanning-type infra-red radiation sensing equipment and other experiments. A solar cell and storage battery power supply will be incorporated. The Nimbus spacecraft project is beginning and we estimate that the first unit will be flown in 1962.

In the second of the two applications areas, communications, we have been working primarily on passive satellite techniques. The 100-ft. spherical reflector, Echo, is the first satellite in this programme. Satisfactory voice, teletype and continuous wave transmission have been made between the indicated stations and between other pairs of stations in the United States. Transmissions between the United States, England and the Continent have also been accomplished. The satellite is made of half-mil thick mylar which has been coated on both surfaces with evaporated aluminim. It carries no instrumentation other than the two small radio beacons which are used to aid the tracking system to obtain

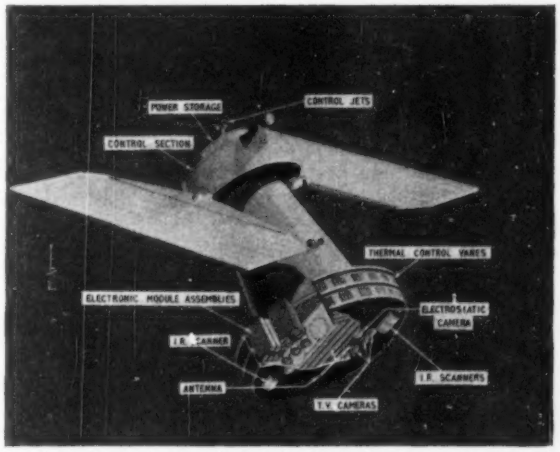
orbital co-ordinate data. Echo I has already been used by the various stations to take a large volume of data on propagation characteristics and has given us a first-hand view of the problems involved in continuously pointing high gain antennas at such a satellite during its periodic passages. The follow-on programme in communications will include work on a rigidized passive reflecting unit and initial studies of the active repeater satellite.

Man-in-Space.

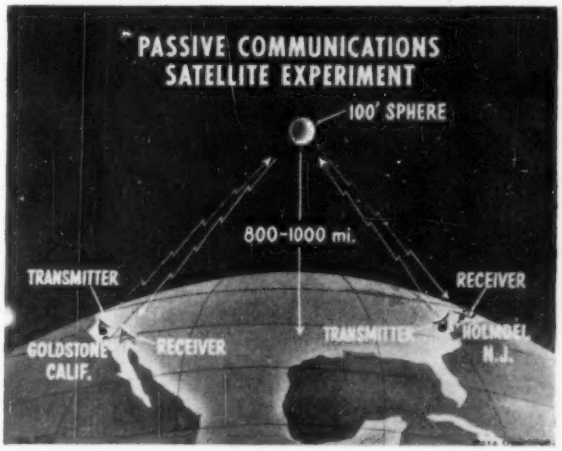
N.A.S.A. has a single broad objective for its manned spaceflight programme. That objective is to provide the capability for manned exploration of space. With this objective in mind, a programme has been outlined in general terms, though it has not yet been officially approved. It represents the thinking of the technical staff responsible for planning the long-range development programme leading to the manned exploration of outer space. The initial step is Project Mercury, a project designed to put a manned satellite into orbit about 120 miles above the Earth's surface, let it circle the Earth three times, and then bring it back safely. We are carrying out Mercury so that we can get some understanding of the problems involved in manned spaceflight before we embark on more ambitious missions. Project Mercury is the simplest way to learn what we need to know about man's capabilities in space at the earliest possible date.

The accomplishment of Project Mercury will mark a tremendous step forward; man's venture into space will immeasurably extend the frontiers of flight. The speed of flight will be increased by a factor of 8 over present achievements, and the altitude by a factor of 5; the environment encountered in spaceflight is one that heretofore has not even been approached. This extension of the flight envelope has required major technical advancements in many diverse fields, including aerodynamics, bio-technology, instrumentation, communications, attitude control, environmental control and parachute development—to mention only a few. By its very advanced nature, therefore, Project Mercury has opened the door for the next step in the manned spaceflight programme.

The next step involves the development of manned spacecraft designed to allow man to perform useful functions in space. We believe this spacecraft should ultimately be capable of manned circumlunar flight as a logical intermediate step toward the future goals of landing men on the Moon and the planets. The design of the spacecraft should be sufficiently flexible to permit its use as an Earth-orbiting laboratory. This is a necessary intermediate step toward the establishment of a permanent manned space-station. Therefore, our present planning calls for the development and construction of an advanced manned spacecraft with sufficient flexibility to be capable of both circumlunar flight and useful Earth-orbital missions. In the long range, this spacecraft should lead toward manned



Configuration of the "second generation" meteorological satellite, Nimbus.



Experimental Communication system using the 100 ft. dia. balloon-satellite Echo I.

landing on the Moon and planets and toward a permanent manned space-station. This advanced manned spaceflight programme has been named "Project Apollo."

It will be be noted that the proposed manned circumlunar flight is a mission consistent with the planned booster capability, that is, with the Saturn vehicle Before circumlunar missions are attempted, Earth-orbital flights will be required for spacecraft evaluation, for crew training, and for the development of operational techniques. In conjunction with, or in addition to these qualification flights, the spacecraft can be used in an Earth orbit as a laboratory for scientific measurements or technological developments in space.

In order to achieve this multiplicity of missions, it may be desirable to employ the so-called "modular concept" in the design of the advanced manned spacecraft. In this concept various building blocks or modules of the system are employed for different phases of the mission. Basically, the spacecraft is conceived to consist of three modules: the command centre module, the propulsion module and the mission module The command centre would house the crew during the launch and re-entry phases of flight. It would also serve as the flight control centre for the remainder of the mission. We anticipate that this module will be identical for both the circumlunar and Earth-orbital missions.

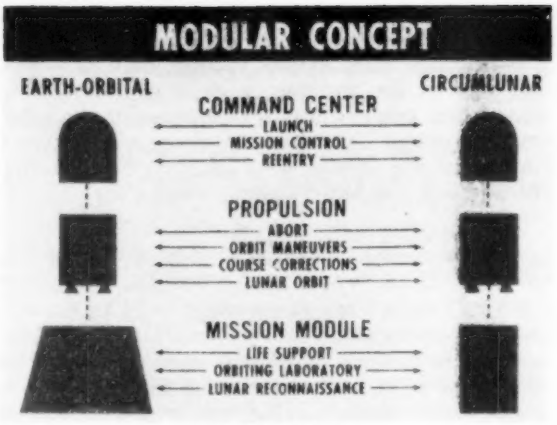
The propulsion module would serve the primary function of providing safe return to Earth in case of an aborted mission. In this sense, it might be compared with the escape tower and retro-rockets on the Mercury capsule. In addition, for circumlunar flight, this component should have the capability of making mid-course corrections; it might also be used to place the spacecraft into an orbit around the Moon and eject it from that orbit. In an Earth-orbital mission, the propulsion module should permit a degree of manœuvreability in orbit for rendezvous with other vehicles. Once again, it may be desirable to provide identical propulsion units for both orbital and circumlunar flights.

The command centre and propulsion units together might be considered, for some applications, as a complete spacecraft, even without the mission modules.

The mission module would differ for the various flight missions. For circumlunar flight, it would be used to provide better living quarters than the command centre can afford, and some equipment for scientific observations. (Detailed design studies may well indicate that the command centre and circumlunar mission modules should be combined into a single package.)

For the Earth-orbital flight, the mission module can be considerably heavier than for circumlunar flight. Hence this module can usefully serve as an Earth-orbiting laboratory, with adequate capacity for scientific instrumentation and reasonably long lifetimes in orbit.

Of all the modules mentioned, only the command centre unit would be designed with re-entry and recovery capability. This module must be designed to re-enter the Earth's atmosphere at essentially parabolic velocity,



Apollo Project.

or about 36,000 ft./sec. It will have to withstand the severe heating encountered at these velocities, and it must be statically stable over the entire speed range from 36,000 ft./sec. to the landing speed.

A degree of manœuvreability will be required to stay within the limits of a rather narrow flight corridor. The boundaries of this corridor are determined by maximum tolerable loads or heating, on the one hand, and minimum aerodynamic loads to cause re-entry in a single pass, on the other. The amount of manœuvreability can be minimized through the provision of adequate mid-course propulsive corrections.

The manœuvreability provided for corridor control should also permit a landing at a fixed point (or within a small area) on Earth. A conventional airplane-type landing is not required. Instead, vertical landings using parachutes or other devices are acceptable. Because of the world-wide aspects of these missions, the vehicle must be capable of surviving both ground and water landings.

An important design consideration is that safe recovery must be possible for both normal and aborted missions. As in the case of the Mercury capsule, it is expected that the most severe requirements will stem from some of the off-design conditions.

There has been a great deal of discussion concerning the role to be played by the pilot in a space mission. Under the assumption that Project Mercury will demonstrate that man can indeed perform useful functions in space, we believe that in all future missions the primary control should be on board the spacecraft.

This guideline is not to be construed as implying that there would be no automatic guidance or control systems on board. Certainly, there are many functions that can better be performed automatically than manually. But the basic decision-making capabilities, and some control functions, are to be assigned to the man.

Because of the possibility of a catastrophic failure of any of the Saturn stages, the spacecraft must be equipped with sufficient propulsion to permit safe crew recovery

from aborted missions. Such capability must be provided for an abort at any speed up to maximum velocity and should be independent of the launch propulsion system.

Some of the requirements for the propulsion module are summarized as follows:

Primary requirements:
- Safe recovery from aborts.
- Course corrections.
- Return from orbit.

Secondary requirements:
- Lunar orbit.
- Manœuvreing in Earth orbit.

Preliminary studies have indicated that, for a circumlunar mission, roughly one-third of the permissible spacecraft weight will be required for onboard propulsion.

In a normal mission, this same propulsion may be applied for course corrections, both while approaching the Moon and when returning to the Earth. As mentioned earlier, the propulsion that must be carried for emergency considerations may, in a normal mission, be sufficient to place the spacecraft into a satellite orbit around the Moon.

For the Earth-orbital mission, the propulsion module would again serve the primary function of providing safe return capability from an aborted mission. If it is not needed for this purpose, then the available impulse might be used for manœuvreing in orbit and for orbital rendezvous with other satellites.

We have tentatively specified that the advanced manned spacecraft should be designed for a three-man crew. Our concept is that, during launch and re-entry, this crew would be located in the command centre unit, but, for the remainder of the flght, at least two of the crew members would be in the mission module.

The use of a pressure suit in the command centre module may be acceptable. But the mission module should definitely be designed to permit "shirt-sleeve" operations, that is, operations without the use of pressure suits. We believe that pressure suits, as currently envisioned, would not be acceptable for the duration of a circumlunar flight.

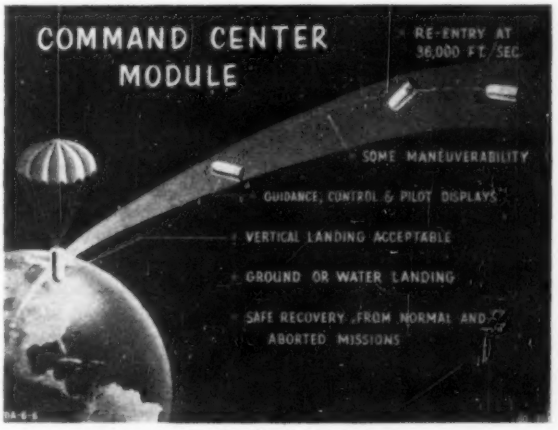
The foregoing requirements apply for both the circumlunar mission and the Earth-orbital mission However, there are other requirements that differ widely between the two types of flight For example, the circumlunar mission module requires an environmental control system that need only provide for about 1 week's life support; on the other hand, it may be desirable to keep the Earth-orbiting laboratory in space for periods ranging from 2 weeks to 2 months.

The circumlunar module would carry only the minimum amount of instrumentation required to complete the mission, whereas a great deal of instrumentation for scientific measurements and observations should be provided in the orbiting laboratory.

The N.A.S.A. centres and industrial contractors have been invited to participate in a programme of system design studies related to Project Apollo. According to the present plans, the systems contracts for the design, engineering and fabrication of the manned spacecraft and its components will probably be initiated in Fiscal Year 1962. However, it should be emphasized that this programme has no official standing as yet. Provision for the initiation of N.A.S.A.'s manned spaceflight programme, beyond Project Mercury, is expected to be included in the Fiscal Year 1962 budgetary request which will be sent to the Congress in January, 1961. With that statement as a basic premise, our present thinking is outlined as follows: Major Mercury flights will probably continue for several years. Research and development, and prototype flights of the advanced manned spacecraft would start in 1962 and to end in 1965. Early flight in in this series would be used to verify final design criteria for the spacecraft shape and its heat protection. It is planned to use the Atlas-Agena B as the launch vehicle for these missions. Following the Atlas-Agena flights, the Saturn vehicle would be used for full-scale development and prototype flights Earth-orbital missions, using the final spacecraft, could conceivably begin in 1966, with circumlunar missions following as soon as the state of both technical and aeromedical knowledge permits such flights.

In summary, our spaceflight programme activities include the space sciences, applications of spaceflight capabilities to projects of direct interest to the general community and the Mercury project to develop the capability for manned exploration of space. In support of these there is an extensive launch vehicles programme. The vehicles programme is endeavouring to increase the reliability of our operations by making repetitive use of a limited number of vehicle systems. The same concept is being worked into the spacecraft planning.

All of this work rests on the broad vase of research and development, in a multitude of specialized scientific and technical fields, which is conducted by the industrial and scientific communities, the military services and N.A.S.A.'s own centres. Without their contributions our plans and programmes would have little substance.


COMMAND CENTER MODULE
RE-ENTRY AT 36,000 FT./SEC.
SOME MANEUVERABILITY
GUIDANCE, CONTROL & PILOT DISPLAYS
VERTICAL LANDING ACCEPTABLE
GROUND OR WATER LANDING
SAFE RECOVERY FROM NORMAL AND ABORTED MISSIONS

Apollo Project

New Look at The Moon

A review feature by H. E. ROSS

"*Strange World of the Moon*"[1] by V. A. Firsoff stands at the Great Divide between the hypotheses of *Telescopic* Astronomy and the realities of *Astronautical* Astronomy, where the conjectures of the former will be submitted to the crucial test of intimate contact with the appearances. There is, however, only casual remark to indicate that the second astronomical era that was born of the telescope has ended. Indeed, the astronautical implications of lunar physical phenomena—their possible utility or malignancy—are not discussed. Let me add that this is not a criticism: on the contrary I offer it as evidence of the author's singleness of purpose, which is to examine the Moon in the light of what visual and instrumental inspection has revealed and to rationalize a welter of conflicting theories. Many people have attempted this thankless task, all too often stretching the appearances to fit preconceived ideas. Not so Firsoff—for him theories must fit the appearances. This is, of course, the correct scientific attitude; nonetheless there are instances where scientists of the highest repute have let ideas run riot at the expense of probability. For instance, Pickering's hypothesis (p. 160) that the irregular changes noted by him in the "runs" of Eratosthenes represented seasonal movements of swarms of small animals. . . . I abstain from adding an exclamation mark at the end of that sentence because it is faintly possible that Pickering was right. . . . On the other hand, it does seem much more likely that he was horribly wrong. . . . And no scientist, especially the most eminent, can afford to be horribly wrong.

This brings me to an iconoclastic remark—that astronomy is not the "exact" science which it is sometimes said to be. In fact, the only *exact* thing about it is the associated mathematics, most of the rest being guess-work. Even so, much of the mathematical proof may be wrong because the premises are wrong. Firsoff himself thinks it necessary to make this point very early in his book—page 3, to be precise. And on page 160 Firsoff clinches the matter by quoting Einstein, who said: "Insofar as mathematics applies to reality it is not certain and so far as mathematics is certain it does not apply to reality."

Firsoff, then, does not rely upon mathematics as a sure guide to truth—in his book mathematical treatments are relegated to an Appendix. He is primarily concerned with submitting the visual and instrumental appearances to systematic investigation; only after considering all the available evidence, which often includes his own lifetime observations and measurements, does he attempt a verdict. Since unlike Firsoff I am not an astronomer and mathematician, I can merely apply common sense to many of his evidences, arguments and conclusions. Only where his discussions impinge upon matters of prime astronautical importance, and so come within the ambit of my own long years of cogitation, am I in any position to doubt or uphold his judgements. But one thing is likely: if Firsoff's conclusions are wrong, then the evidence has probably been wrong. I say this because Firsoff's book is stamped with the hallmark of earnest, reasonable and intelligent seeking for truth. In fact this genuineness is what impresses me most about "Strange World of the Moon."

Second most impressive thing for me is the scope and detail of the matters discussed, notably in terms likely to be understood by most non-scientific readers. There is only one requirement: that the reader wishes to have more information at his disposal than is contained in most books about the Moon. Indeed, "Strange World of the Moon" miraculously achieves two almost diametrically opposed things—it is both "popular" and specialist. That is to say, the layman will understand it; astronomers—amateur and professional—can *use* it. The layman can sit at his fireside and yet enjoy an expertly conducted tour of the mysterious lunar terrain—amateur astronomers, book in hand before their telescopes, can study the familiar features with new insight, zest and determination—and professional astronomers may well find reason to forsake their beloved galaxies of outer-outer space to resume a lapsed interest in the Moon. Remarking this latter-day aberration, Firsoff comments:

"The profession has largely abandoned the Moon, and to a less extent all planetary studies, to the amateurs and devoted its energies to the more promising fields of stellar enquiry. In the words of the meteorist R. B. Baldwin, the Moon has become 'a subject anathema . . . because of its inteference with other delicate observations.' Thus if the amateur reported an observation which was out of joint with the established doctrine it could always be said that he lacked professional qualifications and his report was unreliable. The professional himself, on the other hand, could seldom find time for the time-consuming observation of the Moon, and rested content with taking a few photographs or propounding theories."

Astronauts, then, are not the only people open to the charge of having their heads in the clouds and their feet firmly planted in space. In any case, why indeed should professional astronomers go on propounding theories about the Moon and planets when these may soon be proved wrong by interplanetary busy-bodies? Again, one may wonder how much of the "utter bilge" attitude to space flight is engendered by subconscious fear of being proved wrong—and (ultimate disaster) proved wrong whilst still alive. . . . Nor should astronomers forget that their giant cosmic telescopes have cost millions with far less prospect of utilitarian return than that promised by homely interplanetary rockets.

In the meantime, however, a great deal more may be found out about the Moon by means of telescopes and their accessories; things which if established with a reasonable degree of certainty would facilitate landings, the design of lunar transport, and plans for an exploratory base. For instance, we want to know where there is flat firm ground for touchdown, and what prospect there is of discovering easily acquired payload-saving prime essentials, such as ice or water, from which, using solar power-plants, we might derive oxygen for breathing and hydrogen for fuel and other combustion purposes—whilst also, of course, having use of on-site water for drinking, culinary preparations, ablutions, etc.

In "Strange World of the Moon" much space is given to evidential discussions about the probable nature and state of various parts of the lunar surface and the prospects as regards presence of ice and water. Summing up by and large about the former, Firsoff comments (p. 26): ". . . this is rough ground, largely impassable to any landborne transport, even at first sight, and it may well prove still more impassable than it looks."

That is a very sweeping generalization; but when we learn (p. 67) that both the ground of the light areas (of "lunarite") and the ground of the dark area (of "lunabase") may be pumicelike in nature, or worse, and less dense than water, the problem of vehicular movement over the surface looks formidable indeed, even without the additional hazard of fissured ruggedness in all magnitudes which observation indicates and theory predicts.

The most that can be said is that the dark marias and darkly flooded crater floors, though certainly profusely pitted, corrugated and fractured, are to be preferred as touchdown areas and testing grounds for exploratory parties equipped with tracked vehicles. And before then we shall, of course, possess the experience of robots in respect of landing and movement in specific localities. Beyond this I take refuge in believing that the ingenuity that has largely conquered the forbidding Antarctic terrain, and which will take us to the Moon, will not fail to solve the problem of traversing much of the lunar surface.

Another obstacle to lunar exploration, either on foot or by vehicle, might be the presence of a surface layer of dust, perhaps just a sprinkling, but in places forming deep pools and treacherous "quicksands." In view of the tremendous upheavals which certainly have occurred on the Moon, together with erosive processes which have patently operated, one might reasonably assume that the Moon's surface is very dusty. In any case, it should be covered with a thin layer of cosmic and meteoritic dust and debris. If I recollect correctly, the amount of meteoritic dust which the Earth has collected from space during its existence is estimated as equivalent to a 1-in. layer over the entire globe—and the Moon, even allowing for its lower gravitational attraction, should have a dressing of this sort. Strangely, however, the Moon does not seem so dusty as it should be. Firsoff remarks this in the following passage of page 104, saying: "If now the Moon is covered by volcanic or meteoritic dust, as polarimetric data appear to show, one would expect all colour, nay, difference of tint, to have been entirely effaced beneath a uniform grey pall. . . ." Firsoff's explanation is that the existence of areas of differing shade and colour therefore "constitute indubitable evidence of change on a considerable scale within recent and present time, which it is simply impossible to brush aside." This, then, is one example of Firsoff's non-acceptance of instrumental evidence when that is flatly contradicted by appearance and reasoning. I myself would add, that the presence of lunar surface deposits of meteoritic debris (which we are certainly entitled to expect), is of great astronautical significance. Not only is it almost the *only* thing we can take for granted as being present, but it will be of great service. In short, vast quantities of meteoritic iron and nickel will be available on or very near the surface, simply waiting to be located or collected by magnetic sweepers. . . . "If seven maids with seven mops. . . ."

Incidentally, as a by-product of his discussions about lunar dust Firsoff introduces an argument by Öpik which seems to me the strongest evidence yet for the existence of vegetation on Mars. Öpik's point is simply that the green areas must have regenerative powers such as vegetation alone is capable of providing, because otherwise the deposits of the frequent dust-storms would long ago have rendered them indistinguishable from the rest of the surface.

Turning now to Firsoff on the subject of lunar water and ice, we find his evidence and conclusions hearteningly optimistic. He advances good reasons for believing that water (perhaps heavy water) may be found on the surface in clefts or deep craters; likewise ice, hoarfrost and even snow. In the permafrost just below the surface and under the bowls of the lunavoes he forecasts "black muddy ice heavily permeated with mineral material"; and in a spelaeologist's heaven of underground caverns "measureless to man" he predicts accumulations of water on a considerable scale—even the possibility of a "sunless sea." Astronautically, one could scarcely wish for more. I hope Firsoff is right. . . . And with the possible exception of the "sunless *sea*," which I fancy Firsoff himself intends mainly as a poetical exaggeration, I think he may well be right.

Firsoff devotes Chapter 12 to the much debated lunar atmosphere. Truly enough the author remarks: "On its existence, in however tenuous a form, many issues are hinged"; but those issues are probably of second importance astronautically, for the lunar atmosphere is manifestly very scanty. Nonetheless, Firsoff demonstrates that even a highly rarified atmosphere might be able to produce phenomenal effects—for instance, causing grand-scale erosion and altering surface hues periodically with temperature, generating local mists (which indeed have been reported), and even giving rise to very low-lying cirrus clouds and underground vapours. More—in

Chapter 16 he shows that it cannot be taken for granted that the Moon is absolutely devoid of bacterial and plant life. Indeed he examples various terrestrial forms which might manage to subsist on or in the Moon. On the other hand, the past history of the Moon being unknown, it is impossible to form a conclusion as to whether life as we know it could have originated there. However, there is, of course, a possibility that the Moon may have generated its own brand of life; to us, maybe, only a second rate, a "Brand X" kind, but nonetheless *Life*.

When I was a boy all the lunar craters were contentedly and decently extinct volcanoes. . . . Then suddenly they all became meteor craters. . . . This magical metamorphosis surely proves one of two things—either (*a*) cataclysmic changes *do* take place on the Moon, or (*b*) catastrophic changes take place from time to time in astronomical dogma.

I am glad to find that Firsoff (himself once a professional astronomer) navigates safely between Scylla and Charybdis. He accepts the reasonable assumption that the Moon has suffered meteor bombardment, but ascribes most of the crater formations to a diversely specialized and mostly un-terrestrial vulcanism. This refusal to be trapped into "black or white" oversimplification frees Firsoff to offer reasonable explanations for the processes which have operated to produce such different features as craters with and without central mountains, deeply funnelled craters, craters convexly and concavely flooded, and bubble pits and domes.

Although I am not competent to judge whether all Firsoff's theories on this subject will be confirmed by lunar explorers, I too, believe meteorites did not cause all or anything like all the lunar craters. Perhaps some better insight into their nature and origin might be got by studying their distribution according to type, with reference, of course, to the kind of terrain in which they occur. . . . But then, for all I know this may have been done.

Firsoff devotes eleven consecutive pages plus remarks elsewhere to the results of observing the Moon through monochromatic and dichromatic filters ranging from ultra-violet to extreme red. Since Firsoff has himself specialized in careful colour-filter studies to the extent of several hundred determinations over a period of three years, his comments are all the more worthy of note and respect. The advantage of these filter observations is that they can be used for better discrimination and comparison of hues and tints in various parts of the Moon, whilst differences in brightness can also be more easily seen in this manner than is possible without filters. Again, they offer some prospect of establishing whether a tenuous low-level atmosphere exists and whether the "mists" sometimes noted in certain localities are in fact mists. Unfortunately the method suffers the disability, classically represented by the "canals" of Mars, that different people see different appearances; moreover, the instantaneous appearances cannot reliably be "fixed" by photography. Nevertheless it seems certain that some areas of the Moon do change in hue during the lunar day, that mists are sometimes present, that the Moon is in fact more colourful than was once supposed, and that further colour filter studies should be undertaken and the method developed with a view to obtaining reliable results.

On the other hand, the appearances as seen from Earth, whatever the method of observation, may be intrinsically unreliable. Indeed there are countless questions about the Moon that can only be solved by going there. In the meantime Firsoff's book offers all that can be expected—the most probable answers possible from universally imperfect knowledge.

Not the least intriguing thing to me about "Strange World of the Moon" are some of the illustrations—which though not numerous are adequate. They include excellent photographs of the Moon and several detail drawings made by the author. The former, together with a map of the Moon, permit identification of topographical detail discussed in the text; the latter depict among other things some interesting variable features. Especially deserving of mention and scrutiny is Plate V, where the author's drawing of a cratered peak in the neighbourhood of Saussure stands next to an astoundingly similar photograph of volcanic formations in Tanganyika. Scarcely less remarkable is another photograph on the same page. Here a typical lunar crater is seen from a height of 25,000 ft. . . . only it, too, happens to be in Tanganyika!

In reviewing "Strange World of the Moon" it has not been possible for me to comment upon more than a minute fraction of the subject-matter, and I am afraid that my own remarks have intruded at the expense of more complete coverage. However, there is a remedy—one which I strongly recommend to all readers of *Spaceflight*—read "Strange World of the Moon" for yourselves. In my opinion it is in all respects a Five-Star must.

REFERENCE

1. *Strange World of the Moon.*—An enquiry into lunar physics. By V. A. Firsoff, M.A., F.R.A.S. Hutchinson of London. 225 pp., 25s.

Do-it-Yourself

"The slice of our environment which can now examined is four times greater in volume than it was in 1957, and this examination is, day by day, being performed for us without cost by the spent carcases of some twenty satellites now in orbit. All we have to do is to observe them occasionally from our back gardens when the weather is propitious and make some quite simple calculations. Space research is one subject where discoveries can still be made cheaply and with simple apparatus."—D. G. King-Hele in "Some discoveries from satellite orbits," *The New Scientist*, 3 Nov., 1960, p. 1196 (Vol. 8, No. 207).

Designing For Man in Space

By R. P. HAVILAND*

In this original contribution, a well-known American rocket engineer outlines the results of a preliminary design investigation for a Zero "G" manned rocket station.

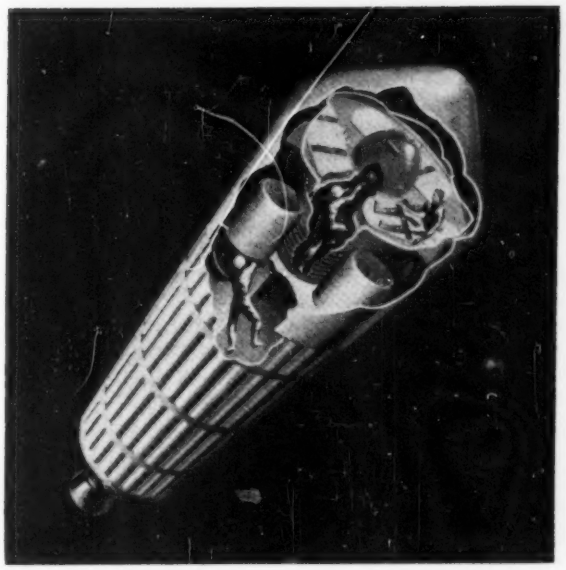
Introduction

This paper investigates the nature of the space vehicle to be used in the period immediately following the first injection of man into space. For this purpose, it is assumed that the first manned programme is approaching its conclusion and that man has been, or soon will be, put into space. It is also assumed that a satisfactory solution has been found to all launch, re-entry, recovery phases of the operation. It is further assumed that the man has remained in his "acceleration couch" or seat for the entire duration of the flight and that no unusual effects were noted beyond the transient disturbances found for the dog Laika in the Sputnik III test.[1]

The questions which then arise as to the nature of the next programme include a number of broad factors which relate to "why man in space?"; a number of more specific questions concerned with the development of space technology; and finally, a number of engineering questions relating to the design of the vehicles to be used. For this study, it is assumed that the next programme must provide further information on the basic problem of the capabilities and limitations of man in space, and must provide information on new problems not investigated in the first programme. The solution should include the ability to extend the exploration of space and should also permit initiation of consolidation of the areas already explored. These two factors imply that the vehicle should be suitable for some specific application in near space and should also be suitable for extending the penetration of space.

Both exploration and consolidation imply that man must stay in space for an appreciable period of time. Therefore, one of the fundamental design features of the second manned programme is the provision of those elements necessary for long-term operation. Here "long term" means long as compared to the early programme. A reasonable design duration will be considered later.

The second fundamental problem for which a solution must be found is operation under conditions of zero g, or more precisely, in the state of free fall about the central body. It appears that certain classes of vehicle application will require this free fall state for their entire life. Other applications do not require it generally, but even in these there will be periods when operations or manœuvres must be conducted which do involve free fall. Since this is a fundamental consideration which cannot be studied to any great extent on the surface of the Earth, it appears desirable to design the second manned vehicle to provide a long duration free fall condition.



Artist's impression of complete spacecraft described by the author.

In addition to these two basic considerations, there are several others which may be included. One of these is investigation of the radiation belts and the general radiation level in space. Properly, this should be done in other vehicles including measurement probes and biological research satellites of the type previously discussed. For this study, it is assumed that a separate investigation programme is being conducted and that the problem to be solved with this design is the provision of a relatively limited amount of radiation protection, suitable for operation inside the limits of the radiation belt.[2]

A second additional item concerns the use of closed or partially-closed life support systems. The basic work for these can be done on the ground. General considerations of weight indicate that long-term operation under open-cycle conditions is unduly heavy. Therefore, it appears that this vehicle should be designed to provide at least a partially-closed life-cycle system.

The final additional item is that the vehicle should have some practical use. Because of the early nature of the programme, it seems that this usefulness may reasonably be limited to a programme of scientific research. This should include study of the space environment and may

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include items of special interest such as investigation of solar and planetary atmosphere, a survey of the heavens in the ultra-violet and so on. The programme may further include a number of investigations leading to the development of Earth oriented applications such as meteorology and communications. For this study, the basic design features will be investigated first. Some attention will then be given to this research application.

Design Features

The major features of the vehicles will be determined by the necessity of investigating and solving the zero g condition and of providing a relatively long operating life. Zero g means that all bodies in the vehicle will have zero weight but will, of course, have mass. Zero g also means that all weight-produced friction is zero. Most of man's normal actions are based on manipulation of himself and his associated objects under the conditions of weight and weight-produced friction. This means that many if not all of man's learned actions will not be possible. For example, he cannot walk, sit, or lie down. These concepts literally have no meaning except in the presence of a gravitational field. A completely new set of body manœuvres must be learned and concepts and terms developed for these.

In the same fashion, many of man's common actions on objects will not be possible. Again, for example, he will not be able to push or pull in his normal fashion. He will not be able to write on loose paper or to turn valves or to drink from a cup in his usual way. Again, new actions which are correct for objects having mass but no weight and no friction must be learned.

This process of learning will require an appreciable amount of room, that is, of space to move in. Because man's early attempts will be clumsy, this learning process will also require protection against personal injury. This implies that the "learning room" be a relatively simple area containing no sharp projections which could cause personal injury. Certain aids to learn may be desirable such as hand-holds, "life-lines," magnetic surfaces for attraction clips and so on, although this may not be necessary in view of the fact that man's muscles cannot produce extremely high velocities.

This learning process is apt to require an appreciable amount of time. This is one of the two basic reasons for long-life design. The second reason for extending the life of operation is to provide time for investigations to be conducted after the learning process is well along.

In addition to the volume which will be needed for the learning programme, volume is required in any event for the routine operations of maintaining life. This includes volume for eating, sleeping, sanitation, exercise and relaxation. Further, volume will be required for instrumentation and measurement, for accessibility to these and to the equipment of the ship.

If an attempt were made to satisfy all of these requirements separately, the vehicle would be both large and massive. Since the present state of the art of rocket development does not allow large weights or sizes, the design of this first manned vehicle must be based on multiple use of the various parts of the vehicle.

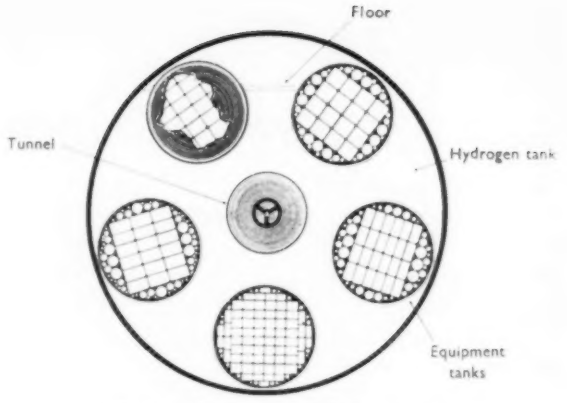

FIG. 1. Cross-section of tank cluster.

The solution of this problem can be obtained by remembering that the complete problem of a spacecraft of this type is composed of three sub-problems. For simplicity, these may be regarded as the problem of man into space, man in space and man from space. The basic nature of the man in space problem has been considered above. The solution to the complete problem must be sought in the "man into space" and "man from space" problems and in the interrelation between these and the problem of man in space.

It seems that consideration of the problem of returning man from space should be based on present technology. At the present time, the ballistic mode of re-entry is the only one which is fully developed. Solutions are available for this which involve the use of a heat sink material to absorb the energy released during re-entry. Additional solutions are available involving a wide variety of materials which provide heat protection by sublimation, evaporation and/or erosion, the entire process being termed ablation. It may be noted that "Teflon," which was the material first proposed for this protection, was used in flight as early as 1950 by the author. Ample theoretical and experimental data is available for either design.[3] Designs have also been prepared and tested which involve the use of parachutes to secure a low velocity impact with the ground as required to prevent structure and personnel damage. It should also be noted that the ballistic type of re-entry has no problems involving moveable aerodynamic surfaces and their control, although there is a minor problem of securing satisfactory initial conditions at the start of re-entry.

The weight of the heat protected material required during re-entry varies with both the area to be protected and the mass which re-enters. Additionally, the weight of the propulsion system which is required to modify the flight orbit into a re-entry trajectory varies with mass. These factors indicate that the re-entry body should be small.

During the ascent period, there is a finite risk of failure. Because of this, it is desirable that the crew be provided with a means of emergency escape. In the early part of the flight, this is relatively simple, but as the velocity increases, the problems become at least as severe as for re-entry. This indicates that the ascent emergency system and the re-entry system should be the same.

Since the problem of man in space appears to require an appreciable volume and therefore mass, while the problem of ascent and descent is best solved with a relatively small and specialized structure, it appears best to separate completely the problem of living in space and the problem of going to and from space. In essence, there should be a part of the vehicle to solve the problem of man in space and a second part to solve the problem of man to and from space. These prolems can be solved nearly independently.

Since the final stage of the ascent rocket automatically goes into orbit along with the ascent capsule, it appears that the desirable multiple use of material can be accomplished by using the rocket propellent tanks to provide the basic volume for living in space.[4] If this is done, a considerable variation in size of the enclosed volume is possible without appreciably affecting the take-off weight since the burnout velocity of a multi-stage rocket is not greatly sensitive to the velocity increment provided by a given stage.

Consideration of the hazard due to meteors and to space radiation shows that the living volume should be enclosed with relatively thick and dense walls. This heavy wall construction is also indicated by the working safety factor of the enclosed space, since this means that there will be a much lower risk of a catastrophic structural failure.

These considerations indicate that at least the final stage of the ascent rocket should be based on pressurized feed of fuel from the tanks to the rocket motor. Studies of the comparative performance of turbo-pump and pressurized rockets indicate that there is some reduction in performance of the pressurized unit as compared to the turbine pump unit but that this is relatively small for a terminal stage, since there are no particular requirements for high acceleration.

Since the empty propellent tanks become the living space, it seems evident that the propellent should be non-toxic. Further, it should be free of unpleasant after-effects such as odour or irritation. An appreciable simplification in design is possible, if one propellent is oxygen. This also is desirable from consideration of multiple use since the reserve propellent can become the reserve oxygen supply. Further, if the propellent reserve is biased so that the fuel reserve is the smallest, it is readily possible to supply the needed oxygen for the duration of the trip. The penalty in this need not be large since the oxygen requirements of about 2 lb./man/day amounts to a total of only 400 lb. for a three-man, 60-day trip, including an allowance for leakage. This time duration will be used for further study.

For the fuel supply, a major consideration is that of obtaining high performance to compensate for the relatively lower performance of a pressurized rocket. Consideration of volume indicates that a low bulk density is not detrimental in this application since large tank volume is desirable. These factors suggest strongly that the fuel should be liquefied hydrogen. An additional consideration is that the residual hydrogen may be burned with some of the oxygen to provide a supply of water for reserve or even the main water supply. This again gives a desirable multiple use of materials.

The combination of hydrogen and oxygen as propellents appear to have only one drawback—the fact that they are not liquid at normal temperature. This, however, may be compensated by using the heat generated by the formation of water to heat residual oxygen and the propellent tanks to normal temperatures.

Since the hydrogen tank will be approximately four times the size of the oxygen tank, it appears to be satisfactory to utilize only the hydrogen tanks for living space. The oxygen tank may be left in the pressurized condition which will permit the use of a direct feed to the cabin through an oxygen make-up system. The residual hydrogen would be burnt to supply water, the remainder being bled overboard.

A previous study[5] has indicated that the air system for the ship should be based on the normal oxygen/nitrogen mixture of Earth. Since the nitrogen is not consumed, only a relatively small quantity of this is needed. While multiple use of the nitrogen could be obtained by using this gas for the pressure drive for the oxygen tanks, this does not seem worthwhile in view of the amount of nitrogen needed and in view of the complexity which would be added to the direct oxygen feed system. Therefore, it seems best to carry the nitrogen in separate small pressure vessels. This nitrogen supply can readily serve for the actuation of values so that some multiple use would be obtained.

Vehicle Layout

The general layout of the vehicle is determined from the following considerations: First, access between the ascent/re-entry capsule to the hydrogen tank is needed. Consideration of launch safety show that it is desirable

Weight of Heat Protection	Low	Very High	Low	High	High	High
Aerodynamic Stability	Good	Very Low	Satis-factory	Very Good	Very Good	Very High
Useable Internal Volume	Good	High	Good	Good	Low	Good
Access through Heat Shield Needed	(1)	Yes	(1)	No	No	No
Rotating Seat Needed	(1)	No	(1)	Yes	Yes	Yes
On-water Stability	Low	Very Low	Good	Very Low	Very Low	Very Low

(1) Either a rotating seat or access through heat shield is necessary.

FIG. 2. Possible re-entry vehicle shapes.

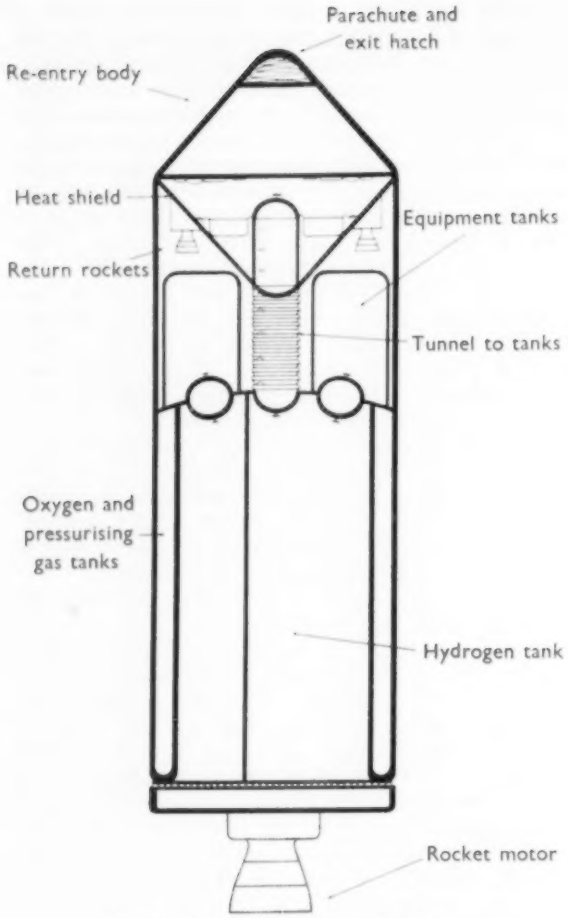

FIG. 3. Space-vehicle principal features.

for ascent/re-entry capsules to be located at the forward end of the vehicle so that the hydrogen tank would be immediately below the capsule. However, the vehicle control tends to be somewhat simpler if the centre of gravity is well forward of the rocket engine. This condition is not satisfied with the arrangement of payload-hydrogen tank-oxygen tank-motor.

This suggests that a desirable arrangement is to surround the hydrogen tank with a liquid-oxygen tank. However, this introduces thermal problems. Since, except for end effects, the tank wall weight is independent of the diameter of the tanks, an equivalent effect may be secured by arranging a number of small oxygen tanks around the central hydrogen tank, as shown in Fig. 1. This arrangement also has the further desirable effect of increasing the shielding surrounding the living space. Further improvement in shielding may be obtained by using open area between tanks for nitrogen storage, cable runs and so on.

In order to secure reasonable utilization of the space in the hydrogen tank for living quarters, it appears that the tank diameter should be approximately 8 ft. On the other hand, there does not appear to be good reason for making this very much larger unless the diameter increases in multiples of 8 ft. to provide for multi-floor construction. For this purpose, a single floor would appear sufficient.

The length of the tank has not been fully worked out since studies of the minimum and desirable living space are still in progress. Pending these results, it is assumed that a 20-ft. length will satisfy the minimum condition.

Since the volume of the oxygen tank needed is about one-quarter the volume of the hydrogen tank, the total cross-section area of the small tanks should be one-quarter the area of the large. Equations can be developed by inspection of Fig. 1 to derive the tank radius as a function of the number to be installed. For this problem, a reasonable compromise would appear to be to use 1 ft. diameter small tanks. This gives an overall vehicle diameter of approximately 10 ft. Not all of the possible small tanks would be needed for oxygen so that space is available for nitrogen storage and equipment containers.

The return capsule must provide a sealed space for ascent and descent, and must also provide access to hydrogen tanks for living quarters. It must also provide for: separation; heat protection; acceleration/deceleration protection; soft landing on Earth or water; communications; floatation; emergency exit; internal short-term air supply; self-containing short-term water and food supply; and transfer from orbit to re-entry conditions.

A number of possible cross-sections for these re-entry devices are shown in Fig. 2. Each of these have been tested extensively on the ground and flight data is available on a number, as may be seen by reviewing the literature. For this application, these shapes have been evaluated for: the weight of heat protection required; parachute size; stability during re-entry; stability on water and land; need for reversible seat; area available for external equipment mounting; access to living containers.

The relative order of desirability for each of these shapes is shown by the table. From this, it appears that the shape C represents the best compromise for the conflicting requirements.

The single weakness of this shape is that access to the living tanks through the re-entry protection shield will be required if the complication of moveable acceleration protection is to be avoided. Experimental evidence indicates that this access can be provided without hazard by using a step construction for the shield.

It appears that no particular problems will be introduced by mounting permanently in the hydrogen tank a number of metallic items which will serve the functions of beds, chairs, tables, instrumentation mountings and so on. Many items, however, especially those involving plastics and lubricants should not be exposed to liquid

hydrogen. For this reason, it appears desirable to provide a number of sealed equipment bays at the top of the hydrogen tank, with accessible parts opening into the hydrogen tanks. After the hydrogen tank has been bled to a vacuum, then filled with oxygen and nitrogen, the equipment can be removed from the bays for installation in what is now the living quarters.

The overall design incorporating these basic features is shown by the cross-section drawing in Fig. 3 and by the artist's conception on page 81. In this, it will be noted that a floor or bulkhead has been shown in the living quarters. This has been included from consideration of visual orientation and ease of manœuvreing and is not intended to produce a quasi-Earth environment.

For this design concept, it appears that all of the design and construction problems are quite straightforward with the single exception of the method of attachment of the transfer tunnel to the re-entry body. It is believed that this can be solved satisfactorily by a hydraulic actuated sliding joint involving O-ring seals. A detail design has not been worked out.

The zero-*g* state is readily produced by stablizing the body with respect to the Earth. This may be done by a gyro or horizon stabilizing system, using a "liquid flywheel"[6] for momentum conservation control plus jets for initial removal of angular momentum. Water may be used for the flywheel.

The detailed arrangement of the internal living area is not yet available. Studies of this are currently under way with the view of developing the basic concepts necessary for the establishment of a "spaceship architecture." This approach seems to be necessary since the usual consideration of the man-machine interface does not include continuous occupancy. It is anticipated that these studies will be reported later.

Use of the Vehicle

The question may be asked "why should this vehicle be built and flown?" It would appear that there is sufficient justification for this programme in the increased knowledge which would be made available. In addition, however, it is noted that this vehicle would be a useful tool since it would provide a reasonable amount of room for a reasonably long operational period. It would be particularly suitable as a space observatory.

For planetary astronomy, for example, a telescope could be mounted so that observation can taken place from within the vehicle. Ref. 7 may be consulted for concepts of a number of telescopes which would be suitable for such a design. Solar astronomy and especially spectrographic work could be conducted in a similar fashion.

Meteorological studies could readily be conducted from a satellite through direct review of the Earth or by "vision plates" which are in reality a closed-circuit television link. There is a large additional field open for investigation in zero-*g* chemistry and physics.

Since the vehicle is designed for relatively long flights, it would also be suitable for flights to a greater distance from the earth such as lunar circumnavigation. Here, a possible extension would involve orbiting the Moon for an appreciable period of time for detailed studies of the terrain and the lunar environment. It does appear possible to use the vehicle for planetary flights but it may be noted that the design concept could be extended. Additional studies of this are needed.

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Full-size mock-up of the soft-landing Moon-probe Surveyor at Caltech's Jet Propulsion Laboratory in California. Hughes Aircraft Company are to build seven such vehicles under a N.A.S.A. contract. Note surface probe device in foreground, tripod landing-gear, and solar cell panel on top of vehicle.

Sixty-six days on Algae

A mouse named Amphex was removed from a sealed-off glass chamber in the Research Division of Chance Vought on 12 August after spending 66 days cut off from the outside world in the interest of aiding the spaceman of the future.

The mouse—whose name stands for animal photo-synthetic experiment—had derived his life-giving oxygen supply solely from algae, a single-celled plant commonly found in ponds. The algae, in turn, lived and grew on carbon dioxide exhaled by the mouse.

Dr. Russel O. Bowman, research scientist in bio-chemistry for the Research Division, said that to his knowledge Amphex spent more than twice as long in an isolated system as any previous test subject.

Purpose of the experiment is to create a closed ecological system which, on a larger scale, would produce vital oxygen and food for man in space or during exploration of a lifeless planet.

Dr. Bowman said that one of the most significant findings was that the algae used kept the chamber free of carbon monoxide, methane and other toxic substances.

Researchers have found indications that some strains of algae, notably the blue-green varieties, produce small amounts of carbon monoxide. Methane and other poisonous gases such as hydrogen sulphide are generated by animals. These substances could be lethal if they built up in the system over a period of time.

"Our experiments have indicated that the chlorella pyrenoidosa strain of green algae does not produce carbon monoxide and that it is effective in removal of toxic substances produced by animal life," Dr. Bowman said.

The mouse was removed from the chamber because its water supply was exhausted. Original goal of the experiment had been 60 days in the chamber.

Dr. Bowman said the mouse was alert and active and appeared to be in excellent condition after his 66 days of confinement.

Both food and water were sealed in with the mouse for this experiment. Certain salts and nitrogen-yielding urea were added to the algae medium.

In future experiments company research scientists intend to feed the mouse on algae from the system and supply urea for the algae from mouse urine. Ultimate goal is a closed system which will provide oxygen, food and water for man and allow reprocessing of human waste.

Applicable to Humans

"The current experiments are giving us a good indication that man could survive a long space trip depending on algae for his oxygen and food supply," Dr. Bowman said.

A regenerative system such as Chance Vought's is needed for distant spaceflights because of space restrictions in a spaceship. One man would require more than 2 tons of food and water and more than 180,000 quarts of oxygen for a relatively short 516-day trip to Mars, Dr. Bowman pointed out.

Company experts feel an algae system may be the answer to spaceflight provisioning because algae use light more efficiently than any other plant, can more than double their number in a day and can be harvested continuously for food rich in protein. Loaded with chlorophyll, algae also act as purification and odour-removing devices.

Almost flavourless, algae also can be treated to taste like many varieties of food, including steak, fish, coffee and desserts. They have a caloric value of about 5 calories/g. of dried material, compared to 4 for sugar and 9 for butter.

The Research Division's mouse was housed in a large glass jar connected to an algae tank by an air-tight system of pumps and tubing. The algae lives and grows in a double-walled plastic tank containing about 4 quarts of water. The necessary light for the algae is provided by fluorescent tubes.

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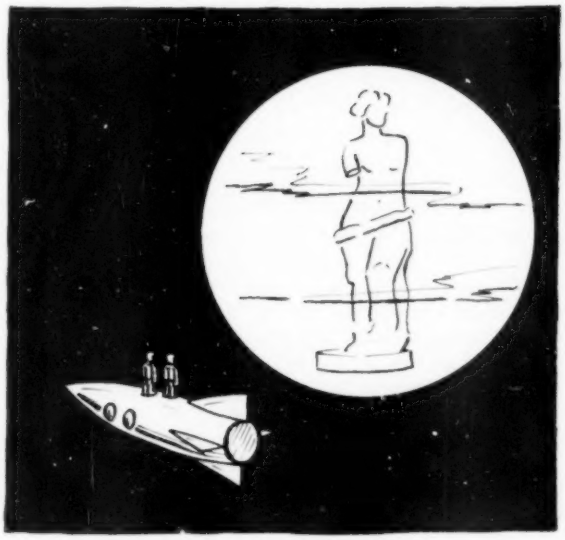

"They'll never believe us!"
Stuart W. Greenwood

Film List

Compiled by L. J. CARTER and G. W. SAVAGE

Title	Distributor	Running Time	Hire Charge	Description	Content
Storms on the Sun	A	13 minutes	Free	16 mm. sound black and white	Shows disturbances in the solar photosphere, recorded by the Commonwealth Scientific and Industrial Research Organization, Division of Physics, Australia.
The Sun and Radio Waves	J	23 minutes	Free	16 mm. sound colour	A popular account of the influence of the ionosphere on radio telecommunications. The film also includes shots of sunspots and solar protuberances.
Energy from the Sun	G.B.	11 minutes	10s.	16 mm. sound black and white	Describes the chemical reactions taking place within the Sun, the reactions which produce the energy to keep life upon the Earth.
Our Nearest Star	M.H.P.	—	Purchase only	16 mm. sound black and white or colour	The properties of the Sun and the relationship of solar activity are explained. Such events as sunspot and solar flares are portrayed.
Explosions in the Sun	R.A.S.	10 minutes	10s.	16 mm. silent black and white	Views of high-altitude observatory and photograph with coronograph of solar prominences.
Ermites du Ciel	S.C.	15 minutes	6s.	16 mm. sound (French) black and white	Describes life in an observatory in the French Pyrenees. Showing French work on solar coronograph, solar prominences, etc.
Eclipse of the Sun	E.T.V.	20 minutes	15s.	16 mm. sound colour	The solar eclipse of 25 February, 1952, total in southern parts of the U.S.S.R. Scientific preparations for observing the eclipse, in Russia, are shown.
The Earth in Motion	G.B.	11 minutes	10s.	16 mm. sound black and white	An explanation of the principles underlying the rotation of the Earth. Topics illustrated include evidence establishing the sphericity of the Earth, its revolution, the characteristics of the orbit, the law of areas, the inclination of the axis, and the seasons.

Title	Distributor	Running Time	Hire Charge	Description	Content
The Flaming Sky	M.H.F.	—	Purchase only	16 mm. sound black and white or colour	The nature of the aurora—the mysterious northern and southern lights—is explored. The film examines present scientific thinking on what the aurora is, what causes it, and its relationship to other phenomena in man's physical environment, including the Earth's magnetic field, radio waves, and solar activity.
Earth and Sky	E.F.	Part 1, 25 minutes Part 2, 20 minutes	£1 10s. for each part	16 mm. sound colour	Part 1: Follows the history of astronomy from ancient to medieval times. Part 2: Outlines the changes in thought between A.D. 1500 and 1700.
The Moon	G.B.	17 minutes	£1	16 mm. sound black and white	A study of the moon and its relation to the solar system. Explanations are given of the Moon's influence on the tidal waves; the Moon's phases are also discussed. Animated diagrams demonstrate the motion of the Moon about the Earth; the movements of the Moon and Earth around the Sun are also demonstrated by means of models. The last part of the film illustrates lunar and solar eclipses.
Moon	G.B.	11 minutes	10s.	16 mm. sound black and white	Tides, Moon's phases, lunar and solar eclipses are shown.
Moon	A.S.G.	26 minutes	£1 5s.	16 mm. sound black and white	Shows photographs of the Moon taken by the Jacksonville Amateur Astronomers Club through their 8 in. and 16 in. reflectors.
Jupiter	R.A.S.	5 minutes	5s.	16 mm. silent black and white	Rotation of Jupiter and passage of satellite near disc showing eclipse shadow.
Solar Family	G.B.	11 minutes	10s.	16 mm. sound black and white	A description, by animated diagrams, of the evolution of the solar system. The Planetisimal Hypothesis is discussed, and the real and apparent motion of the planets portrayed. Descriptions are also given of the planetoids, Halley's comet, and the movement of the solar system in space.
The Solar System	G.F.P.	11 minutes	10s. first day and 5s. each subsequent day	16 mm. sound black and white	Demonstrates the relative sizes of the planets and the Sun, also the distances between them. Forces at work in the solar system, the differences between the planets and stars; the nature of gravity, stellar and solar light and heat are other points covered.

Title	Distributor	Running Time	Hire Charge	Description	Content
Reaching for the Stars	A	10 minutes	Free	16 mm. sound black and white	A record briefly outlining Australian astronomical work. Describing the 74 in. 40-ton reflector telescope.
The Inquisitive Giant	C.F.L.	28 minutes	15s. for first day, 3s. each additional day	16 mm. sound black and white	Describes the Jodrell Bank telescope and its construction. Mention is made of its immediate practical uses, *i.e.*, weather phenomena, tracking of satellites.
Grinding a Giant Telescope Mirror	C.Co.	13 minutes	Free	16 mm. sound colour	This film covers a remarkable feat of optical engineering, the grinding of the second largest astronomical mirror in the world for the Sir Isaac Newton memorial telescope.
Radio-Astronomy in Australia	A	13 minutes	Free	16 mm. sound colour	This film deals with Australia's contribution in the field of radio astronomy and shows some of the equipment used, and the results which it has obtained.
Exploring the Universe	G.B.	11 minutes	10s.	16 mm. sound black and white	A description of the means of exploring the Universe and some of the phenomena discovered there. The principles of refracting and reflecting telescopes are explained. Stars and clusters are examined by special cinematograph techniques, and the film ends up by outlining the theory of the expanding Universe.
Colour Motion Pictures of the Whole Sky	B.F.I.	26 minutes	£1	16 mm. silent colour	Use of the cinecamera and the sphere of an integrating photometer to film entire vault of the sky.
The Great Universe	E.T.V.	40 minutes	25s.	16 mm. sound colour	A journey through time and space, between dusk and dawn. The journey round the solar system, with close-ups of the Earth's fellow planets. Asteroids collide, comets are born, further out stars are born and burn with varying degrees of intensity of white, blue or red heat.
Voyage Across the Impossible	B.F.I.	21 minutes	16s. plus postage	16 mm. sound black and white	This was the second of the longer trick films of Georges Méliès. It shows the Jules Verne adventure of a fantastic group of explorers who went out in a curious machine on a voyage across the Universe and after passing the heavenly constellations find themselves on the face of the Sun.

Title	Distributor	Running Time	Hire Charge	Description	Content
The Stooge	F.E.	24 minutes	Free	16 mm. sound colour	Outlines typical problems encountered in the development of a guided missile by following component parts through the various stages of design, manufacture, testing and assembly. Several proving flights are shown, and results from the trials summed up.
Faster than Sound	C.F.L.	11 minutes	5s.	16 mm. sound black and white	As planes reach higher speeds, a new problem was presented to aeronautical scientists—the sonic barrier. This film describes some dramatic and previously secret experiments, carried out under the development programme of the Ministry of Supply, to discover, by means of a miniature pilotless machine, how these forces could be overcome. Commentary spoken by Sir Ralph Richardson.
High-Speed Flight	S.M.	Total time: 71 minutes	Free	16 mm. sound colour	The film is in three parts:— (i) Approaching the Speed of Sound (28 minutes) (ii) Transonic Flight (23 minutes) (iii) Beyond the Speed of Sound (20 minutes) Deals with the problems encountered in high-speed flight.
High Angle Launch Aircraft	F.E.	8 minutes	Free	16 mm. sound colour	This film summarizes the 1950–52 U.K. and Australian trials to investigate the problems of low "g" high angle launching of aircraft.
The SR53 Flies	W.A.	8 minutes	Free	16 mm. sound colour	The first flight of the SR53.
Test Flight 263	S.M.	38 minutes	Free	16 mm. sound black and white	Shows the problems besetting an aircraft designer, and a visit to the R.A.F. Insitute of Aviation Medicine to see how the human side of high-speed flight is approached.
The Rocket	W.P.D.	Approx. 18 minutes	£1 1s.	16 mm. sound black and white	The past, present and the future of the rocket is examined from its beginning as a Chinese fire cracker, its seventeenth-century inspiration to would-be space travellers, to its present practical applications.

Title	Distributor	Running Time	Hire Charge	Description	Content
Rockets: How they Work	G.B.	16 minutes	£2	16 mm. sound colour	Demonstration of the action and reaction principle upon which the rocket is based. The principle is then shown being applied to rocket construction. The function of a multi-stage rocket and an explanation is given of the steering mechanism.
History of Rocket Development	M.O.A.	120 minutes	Free	16 mm. silent black and white	A German film unaltered from the original form, showing some of the work carried out, in Germany, from the earliest rockets to the 1943 stage of development. Depicts some of the actual experiments and reproduces "stills" of the test rigs, etc.
The German A4 Rocket	C.L.	41 minutes	£1	16 mm. sound black and white	Shows the principle of design, method of assembly, testing and firing of the German A4 rocket.
Research by Rocket	M.H.P.	—	Purchase only	16 mm. sound black and white or colour	The exploration of the upper atmosphere by instruments carried aloft in rockets is explained. The history of man's attempts to reach out into the higher atmosphere is portrayed and the variety of modern rocket vehicles, including their principles of operation, is shown.
Earth Satellites	G.B.	17 minutes	£2	16 mm. sound colour	Begins with an explanation of satellite flight. This is followed by an analysis of the component parts of an actual satellite, and a description of the way in which the satellite will be launched. The relationship between orbital speed and distance from the Earth is then considered, and the film ends by suggesting some of the possible uses of Earth satellites.
Red Moon	E.T.V.	4 minutes	7s. 6d.	16 mm. sound black and white	Photographs of rocket firings. Return of dogs to Earth.
Exploring Space	C.F.L.	25 minutes	30s.	16 mm. sound colour	The development and operation of the modern rocket are demonstrated by Dr. I. M. Levitt, Director of Fels Planetarium, Philadelphia. The film provides an elementary explanation of the physical principles involved in rocket-propulsion, and describes significant scientific advances. It shows why the rocket engine is the only device at present capable of propulsion beyond the Earth's atmosphere.

Title	Distributor	Running Time	Hire Charge	Description	Content
Destination Moon	R.H.	91 minutes	£5	16 mm. sound black and white	A classic of its type, the story of a journey to the Moon. The thrill and excitment of a rocket-ship flight through space.
Blazing a Trail to the Stars	C.F.	45 minutes	£4 10s.	16 mm. sound colour	An example of Russian popular science. It provides a study for the general public of the possible lines of development of space travel. Animated sequences discuss the principle of propulsion in space. An exploratory flight by a team of three men is followed by a detailed account of a full scale expedition which sets up a space station to study radio-astronomy, weather forecasting, botanical and biological investigations.
Science in Space	M.P.H.	—	Purchase only	16 mm. sound black and white or colour	Scientific exploration of space, and its contents, and the placing of satellites into orbits, are explained. Significant discoveries of modern space science are shown, including the Van Allen radiation belts. Radio and optical methods of tracking satellites, the telemetering of data from satellites and space probes to Earth and the analysis of these data are emphasised.
Magnetic Force	M.H.P.	—	Purchase only	16 mm. sound black and white or colour	The nature of Earth's magnetic field is explained, beginning with early speculations. The film shows how the magnetic field controls the paths of cosmic-ray's particles and of charged particles that make up the aurora.
Atomic Theory	G.B.	11 minutes	10s.	16 mm. sound black and white	Starts with the theory as proposed by John Dalton in 1808, and outlines the progress of the nineteenth century, bringing in Faraday's early experiments in electrolysis, Mendeleeff's Periodic Table, and ending with ideas then current of the size of molecules and atoms.
Rays from Atoms	G.B.	13 minutes	£1	16 mm. sound black and white	Demonstrates how cathode rays were investigated and the electron discovered: how positive rays were found and their nature established: how X-rays were found and quickly put to use. The great work of Joseph Thomson is emphasized.

Title	Distributor	Running Time	Hire Charge	Description	Content
The Nuclear Structures of the Atom	G.B.	20 minutes	£1	16 mm. sound black and white	Reconstructs the early work of Becquerel and the Curies on radioactivity and shows how Lord Rutherford's work in this field led to his theory of the Nuclear Structure of the Atom. H. G. Moseley's brilliant work in support of this theory is visually shown by animated diagrams.
Uranium Fission-Atomic Energy	G.B.	14 minutes	£1 10s.	16 mm. sound black and white	The events of recent times leading up to the discovery of uranium fission are discussed, explaining in detail the principal facts of uranium fission. The sequences include a speech by Professor Frisch, who was closely concerned in this work. The making of atomic bombs is discussed.
Atom Smashing—the Discovery of the Neutron	G.B.	21 minutes	£1	16 mm. sound black and white	Describes the tools of nuclear physics and shows machines used to bombard the atom. The work of Juliot Curie and Sir James Chadwick in the discovery of the neutron is explained. The splitting of the Lithium atom in 1932 is discussed and a speech by Professor Einstein explains the similarity between their work and his theory of the equivalence of mass and energy.
Einstein's Theory of Relativity	B.F.I.	25 minutes	16s. plus postage	16 mm. silent black and white	Max Fleischer's popular account of Einstein's Theory is a landmark in the popular exposition of a very difficult subject.
Radio Waves	M.P.H.	—	Purchase only	16 mm. sound black and white or colour	Both man made and natural radio waves are discussed, beginning with the discoveries of Heinrich Hertz in the nineteenth century. The science of radio-astronomy is also portrayed.
Cosmic Rays	M.H.P.	—	Purchase only	16 mm. sound black and white or colour	A detailed examination is made of the present concepts of the origin and nature of charged particles reaching the Earth from outer space. Recent discoveries—using balloons, rockets, and satellites—are presented, and the relationship between cosmic-ray research and nuclear research is outlined.

Title	Distributor	Running Time	Hire Charge	Description	Content
Frozen Air	B.F.I.	11 minutes	8s. plus postage	16 mm. sound black and white	Made in Germany before the war, this is a popular introduction to low temperature physics. Experiments show phenomena associated with liquid oxygen, nitrogen, hydrogen and helium, and the effects of very low temperatures on other materials such as rubber, lead and mercury. English commentary.

Film Strips

Rockets and Space Flight	B.I.S.	—	10s.	50 illus. single frame	Use of rockets for A.T.O., guided missiles, sounding rockets and space exploration.
The Viking Rocket	B.I.S.	—	10s.	30 illus. single or double frame	Various stages in the manufacture, handling test and launch of a large liquid-propellant rocket.

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Questions of Space Law*

By JOHN COBB COOPER, LL.M., LL.D.

Introduction

International peace and the future welfare of mankind demand that the Rule of Law shall be applicable with certainty in outer space. My friend and colleague, Professor Dr. Goedhuis, in his 1960 report as Chairman of the International Law Association Sub-Committee on "Air Sovereignty and the Legal Status of Outer Space," directed attention to the statement made by the Netherlands Representative at the United Nations to the effect that in our dealing with outer space we certainly should not jettison all our ideas of law and of right and justice. With this I fully concur. In fact I am prepared to go further.

President Eisenhower a few weeks ago (22 September, 1960) made a notable address before the United Nations. He said:

> "Another problem confronting us involves outer space. The emergence of this new world poses a vital issue: Will outer space be preserved for peaceful use and developed for the benefit of all mankind? Or will it become another focus for the arms race—and thus an area of dangerous and sterile competition? The choice is urgent. It is ours to make.
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> "Agreement on these proposals would enable future generations to find peaceful and scientific progress, not another fearful dimension to the arms race, as they explore the Universe."

In the background of this statement was the unanimous resolution of the General Assembly of the United Nations adopted 12 December, 1959, entitled "International Co-operation in the Peaceful Uses of Outer Space." It declared that the General Assembly recognized the common interests of mankind as a whole in furthering the peaceful use of outer space and the belief "that the exploration and use of outer space should be only for the betterment of mankind and to the benefit of States irrespective of the stage of their economic or scientific development."

These stirring words of President Eisenhower and of the United Nations General Assembly emphasize the necessity of applying the Rule of Law in outer space. But if this is to be done, certain fundamental questions must be solved. Law, as a rule of human conduct, and international law, as a rule of the conduct of States require clarity and certainty. If the Rule of Law is to be applied in outer space, then I submit, as I have on other occasions, that the area of outer space must be determined, that its legal status be agreed upon, that the rights of States in the area be universally acknowledged and that the legal status of flight instrumentalities to be used in outer space be also fixed. It is unfortunate, and may well be disastrous, that no international agreement now exists on any of these fundamental questions. Until this does exist the objectives stated by President Eisenhower and by the General Assembly of the United Nations cannot, in my view, be successfully reached.

1. *What is Meant by the Term "Outer Space"*

The United Nations, heads of States, diplomats, and jurists continue to use the term "Outer Space" as meaning a geographical area, but as yet without any agreed definition. The original United Nations *Ad Hoc* Committee on the Peaceful Uses of Outer Space, established under the resolution of December, 1958, in its report of 14 July, 1959, expressed the view that the question of determining where airspace ends and where outer space begins was not a question requiring priority of treatment and that any present international agreement on the subject would be premature. With this view I have always vigorously disagreed. I do not believe that the Rule of Law can be established with certainty as to

* *A lecture presented at Leiden University*, 10 Oct., 1960.

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Frozen Air	B.F.I.	11 minutes	8s. plus postage	16 mm. sound black and white	Made in Germany before the war, this is a popular introduction to low temperature physics. Experiments show phenomena associated with liquid oxygen, nitrogen, hydrogen and helium, and the effects of very low temperatures on other materials such as rubber, lead and mercury. English commentary.
				Film Strips	
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outer space, a finite geographic area, unless the boundaries of that area are known and understood. The same United Nations report noted, however, that the upper boundary of the airspace and the lower boundary of outer space do not necessarily coincide. With this view I have long been in agreement.

The legal status of the airspace is well known and is now undisputed. The airspace over a State is subject to the exclusive sovereignty of that State, and, in my judgment, is part of its territory. Certainly that State has sole right to control all flight in the airspace above its lands and waters. However flight over stateless lands and over the high seas is, with certain exceptions, subject to no ulterior control. Admittedly no present agreement exists as to the upper boundary of the airspace. But few would dispute the view that the airspace extends upward from the surface of the Earth through those areas where "aircraft" may be operated which depend solely on the gaseous air for aerodynamic lift to maintain flight. Possibly airspace may extend further upward to include all areas where the atmosphere is sufficiently dense to contribute in any degree to aerodymanic lift, or even higher to include all areas where the atmosphere is sufficiently dense to prevent a satellite's orbit around the Earth. Of these questions times does not permit further discussion here. Certainly, however, the airspace and outer space do not overlap if the airspace is subject to the sovereignty of the State below while outer space is free for use by all.

It was with great pleasure that I learned of the recent action of the International Law Association 1960 Hamburg Conference in adopting a resolution on "Air Sovereignty and the Legal Status of Outer Space" which included a request to the Air Law Committee of the Association to continue its study of "the question of defininig the lower limits of Outer Space."

May I state my personal views? Before Sputnik I was launched, I suggested to the American Society of International Law a new convention: first, reaffirming absolute sovereignty of the subjacent State up to the height at which "aircraft" could be operated; then further extending limited sovereignty upward to 300 miles above the Earth's surface; then accepting the principle that all space above should be free for passage.

In 1957, a few weeks after Sputnik I was launched, I published a memorandum in which I pointed out that my 1956 suggestion was based on earlier and then widely accepted scientific opinion to the effect that somewhere not far below 300 miles the atmosphere had sufficient density to prevent free satellite flight, but that Sputnik I had proved this premise to be unsound. My primary view has always been that the airspace does not include any area in which a satellite may be put in orbit around the Earth.

The most recent data generally available indicates that at least one or two satellites have been as close to the Earth as 100 miles (160 km.), or a little less, at the perigee (lower limit) of orbit. A well-known astronomer has stated that studies of meteors entering the Earth's atmosphere show that the atmosphere below 70 miles approximately (112 km.) is too dense for a satellite to pursue an orbit. It would therefore appear that it may be possible for a satellite to be put in orbit at least once round the Earth at some minimum altitude between 70 and 100 miles (112 and 160 km.) above us.

In this area of possible satellite flight the gases present bear little resemblance to the "air" which we breathe and in which normal types of aircraft may be flown. Distinguished scientists have expressed views which you may find of interest:

(*a*) At the surface of the Earth the "air consists of about 78% molecular nitrogen, 20% molecular oxygen, and small quantities of argon, carbon dioxide, and water vapour.

(*b*) At 50 miles (80 km.) altitude the temperature has dropped sharply, the atmospheric density is only about one-millionth (1/1,000,000) of the surface density, and not sufficient to contribute in any degree to the aerodynamic lift of flight instrumentalities.

(*c*) At 100 miles (160 km.) or less, the temperature has increased up to 2000° F. or more, the atmospheric density has further decreased to one-billionth (1/1,000,000,000) of the surface density, the oxygen molecules have already broken down into separate oxygen atoms. This extremely thin gaseous combination of a few nitrogen molecules, oxygen atoms, and perhaps particles of other gases, has little if any resemblance to the substance, ordinarily called "air," which we breathe and which is needed to support the flight of "aircraft" as envisaged when the Paris and Chicago Conventions accepted the principle of "airspace" sovereignty.

If the lower boundary of outer space is fixed, by international agreement, as the lowest altitude above the Earth's surface at which an artificial satellite may be put in orbit around the Earth, we would then have more than a theoretical boundary. Below this boundary most objects moving from outer space towards the Earth would be destroyed by heat from atmospheric friction. Above the boundary satellite flight would be practical. Also it might be added that biologists hold that at about 100 miles above the Earth's surface human blood will boil.

Considering the entire physical situation as now known I would, therefore, suggest, as I did in substance at the recent Third Colloquim On the Law of Outer Space held in Stockholm during the meeting of the XIth International Astronautical Congress, that, in any international convention dealing with flight into outer space, the following statement might be included: "Outer space, for the purposes of this convention, is defined as the area whose lower or inner boundary is the lowest altitude above the Earth's surface at which an artificial satellite may be put in orbit at least once around the Earth, and

whose upper or outer boundary is the outer limit of our solar system." Flight beyond our solar system, if ever practical, will present new problems.

The wide acceptance of such an agreement would enable the Rule of Law to be applied without difficulty and with certainty in a reasonably definite geographic area. It should be noted that in fixing the suggested lower limit for outer space, no decision is required as to whether the absolute sovereignty of a subjacent state extends upward to this lower limit of outer space or whether, as I have previously urged, it would be well to admit the existence of an intervening area in which national rights of transit might be accepted, particularly for the purpose of launching artificial satellites over the lands and water of adjacent states without violating the territory and sovereignty of the latter, and similarly of bringing back national spacecraft to national territory above the airspace of the adjacent state but below the limit of outer space. I submit the foregoing as worthy of practical consideration.

2. *What Is or Should Be the Legal Status of Outer Space?*

To me it is quite impossible to apply international legal principles in a satisfactory manner in any geographic area whose legal status is unknown. Today the legal status of outer space is as vague and uncertain as was the legal status of the high seas in the centuries before Grotius, in the Mare Liberum, focussed attention on the need of the world to accept the doctrine of the freedom of the seas. Years after that historic event, a great American jurist, Mr. Justice Storey, said in the case of *The Marianna Flora* (1826):

> "Upon the ocean, then, in time of peace, all possess an entire equality. It is the common highway of all, appropriated to the use of all; and no one can vindicate to himself a superior prerogative there. Every ship sails there with the unquestionable right of pursuing her own lawful business without interruption; but whatever may be that business, she is bound to pursue it in such a manner as not to violate the rights of others."

This statement I would urge as a sound solution of the legal status of outer space. But I fear that it can be made certain only by international agreement. I fully realize the arguments that have been made to the effect that the failure of States to protest present satellite flights indicates an acceptance of this status for outer space without further agreement. I also appreciate the force of the arguments which have been made that it is not possible logically to conceive of the extension of sovereignty into outer space. I have also studied with the greatest care and interest the 1959 report of the United Nations Committee on this subject, particularly the following:

> "9. During the International Geophysical Year 1957–58 and subsequently, countries throughout the world proceeded on the premise of the permissibility of the launching and flight of the space vehicles which were launched, regardless of what territory they passed 'over' during the course of their flight through outer space. The Committee, bearing in mind that its terms of reference refer exclusively to the peaceful uses of outer space, believes that with this practice, there may have been initiated the recognition or establishment of a generally accepted rule to the effect that, in principle, outer space is, on conditions of equality, freely available for exploration and use by all in accordance with existing or future international law or agreements."

But we must deal with hard facts. A well-known American lawyer and air law lecturer, Mr. Arnold W. Knauth, pointed out in an address in Buenos Aires on 24 August, 1960, that only about 35 months had then passed since Sputnik I was launched, that since that time there had been, perhaps, less than fifty launchings of other satellites and perhaps 100 attempts, but that these launchings and attempts at launchings "are not adequate to formulate and create any customary law in space."

In a memorandum which I filed with the International Law Association for the Hamburg Conference I suggested:

> "No general rule of customary international law exists as to the subjacent State's rights to control all flight in areas above the airspace, nor whether on the contrary such areas should be treated as free for international flight as the high seas are for shipping, although strong arguments can be made that this should be future law."

It must never be forgotten that the Chicago Convention goes no further than declaring that each State has sovereignty in the airspace over its land and waters. Nowhere does that Convention, nor any other international agreement of which I am aware, state that claims of sovereignty of a State must be limited to its airspace. Jurists may urge doubts as to the right of States to claim sovereignty in areas beyond the airspace, but there is no international agreement to that effect nor am I aware of any formal and binding declaration of any State waiving any rights to claim sovereignty beyond the airspace, even to the far reaches of outer space.

This situation can be rectified only by a new international agreement. As I suggested in Stockholm, such a Convention might include a statement to the following effect, in addition to the statement as to boundaries:

> "The contracting States hereby declare that no State has or can have sovereignty over such area, namely outer space, or any part thereof, or any celestial bodies therein."

If the lower limit of outer space is fixed, as suggested, at the lower limit of the area in which a satellite may be put in orbit around the Earth, and if States agree, as also suggested, that no State can have sovereignty over such areas or a part thereof or any celestial bodies therein, the Rule of Law may be made applicable in a reasonably definite area, whose legal status has been fixed. Two of the fundamental questions now undetermined will then no longer pose threats to world peace.

3. *What are the Independent Rights of Sovereign States in Outer Space?*

To me only one part of this question asserts a fundamental problem. Whether the legal status of outer space be left undetermined as at present, or whether, as I hope, its legal status will be fixed as an area in which no State may claim sovereignty, the right of every State in the international community to act for its individual self-protection and self-defence must be acknowledged and preserved. Time will not permit me to discuss here more than a bare outline of how United States thinking, with which I am reasonably familiar, has historically dealt with this question, applicable in areas on the surface of the Earth and in the airspace.

As early as 1804, Chief Justice Marshall of the United States Supreme Court, one of our greatest jurists, said (*Church* v. *Hubbart*, 2 Cranch 187): "The authority of a nation within its own territory is absolute and exclusive. . . . But its power to secure itself from any injury may certainly be exercised beyond the limits of its territory." This statement still stands in our jurisprudence. It would be directly applicable to the right of a subjacent State to "secure itself from injury" in outer space beyond its territorial airspace.

In 1837, Daniel Webster, as Secretary of State of the United States, said during consideration of the celebrated "Caroline" case, that the necessity which justifies acts of self-defence outside national territory is "confined to cases in which the necessity of that self-defence is instant, overwhelming, and leaving no choice of means, and no moment for deliberation." This statement was cited with approval in the Nuremberg cases after World War II. However, I would point out that no emergency could leave less chance for deliberation than a threat from outer space.

Perhaps the most important analysis of the problem made in the United States is found in an address delivered in 1914 by the late Elihu Root speaking as President of the American Society of International Law. Mr. Root served as Secretary of State and also as United States Senator from New York. In discussing the right "of self-protection" as "a right recognized by international law," he said (8 AJIL-6): "The right is a necessary corollary of independent sovereignty. It is well understood that the exercise of the right of self-protection may and frequently does extend in its effect beyond the limits of the territorial jurisdiction of the State exercising it." Later, in the same address, in a much quoted phrase he insisted upon "the right of every sovereign State to protect itself by preventing a condition of affairs in which it will be too late to protect itself."

May I point out that this principle of the right of a State to act for its self-protection outside its national territory has already been applied in connection with aircraft flight. In 1950 the United States and Canada established air defence identification zones around parts of their respective shores. Admittedly the airspace over the high seas is not territorial space and enjoys the same international status as the high seas themselves. Yet the United States and Canada did not hesitate to establish regulations to prevent unidentified aircraft approaching their shores from the seas. The United States regulation, for example, requires that foreign aircraft must report their presence and identification when not less than 1 hr. or more than 2 hr. average cruising distance via the most direct route to the shore. This is a clear application of the right of self-preservation and self-defence applicable outside national territory and within international flight space. It would seem that the same right exists for subjacent States to act in outer space above national territorial airspace to the extent deemed necessary for the protection and defence of the lands below.

Certainly any future agreement for international regulation of outer space flight, or control of outer space, must preserve such national rights of self-protection and self-defence. It is submitted that nothing in the United Nations charter is opposed to this view. While Article 51 deals solely with the right of individual or collective self-defence "if an armed attack occurs against a member of the United Nations," it is my firm belief that this does not take away already existing international law rights of self-protection which have long been supported as part of the international law applicable to all States.

4. *What is the Legal Status of Satellites and Future Spacecraft?*

In the law of the sea the legal status of the waters used and the vessels employed has long been settled. The high seas are free for the use of all. Territorial waters, bays, harbours, and rivers have certain varying national characteristics. Vessels employed are said to have the "nationality" of the State of the flag. Under the law of the air, as exemplified in the Chicago convention, the legal status of the airspace has been fixed, and it was agreed, as in the predecessor Paris convention of 1919, that aircraft should have nationality.

The meaning of this term "nationality," as applied to ships and to aircraft, is quite well known. It symbolizes the acceptance of a rule of international law which states that a special relationship exists between a particular State and the transport instrumentaility which has the "nationality" of that State. The effect of this special relationship is that the State of the flag is responsible for the international good conduct of its vessels and its aircraft when in use beyond national territory. And reciprocally, that State has the right, as against other States, to see to it that its national vessels and aircraft are accorded the privileges and rights to which they are legally entitled when away from home. This is a rule of public law and not of private law. It does not make the State of the flag responsible for such things as debts incurred in the operation of the vessel or the aircraft, but it does make the State of the flag responsible if such vessel or aircraft violates a rule of international law affecting the rights of other States.

International law writers have often pointed out that on the high seas, uncontrolled by any national sovereignty, chaos would be the rule but for the fact that the principle of nationality of vessels has for centuries been accepted into maritime law, and that with this concept international order may be maintained. The State of the flag of each vessel is responsible for the latter's good conduct while passing over the high seas where no national territorial sovereignty exists.

It is interesting historically to note that the necessity of balloons having this quality of "nationality" was suggested in one of the earliest air law discussions. Fauchille's major thesis in 1902 and 1903 was that the air was free. But as a very able international lawyer, he accepted the fact that chaos might result if the instrumentalities in flight did not have the nationality of some particular State.

A few years later the problem was discussed at length at the 1910 Conference called by the French Government. While the Conference did not, for very different reasons, conclude a Convention to regulate flight, no serious contention was ever made later against the application to aircraft of the maritime principle of "nationality." In fact this principle was widely recognized in the conduct of States between 1910 and the signature of the Paris Convention of 1919. For example, neutral States, such as very notably the Netherlands, enacted and enforced rules during World War I which outlawed the flight of foreign aircraft over Netherlands territory. At the close of the war, the nationality of aircraft was recognized in the Paris Convention, as it has been in every subsequent convention regulating air navigation, including the presently effective Chicago Convention of 1944. But the gravest doubt exists as to whether satellites and other flight instrumentalities, which can operate freely only in outer space, are "aircraft" within the present rules of international law dealing with required "nationality." If outer space is to be free for the use of all, the logic of Fauchille must again be applied. Every type of flight instrumentality usuable in outer space must have the nationality of a State of the international community. Normally, this would be the launching State, which would thereby become responsible for the behaviour of the satellite, or other spacecraft, so far as rules of international law are concerned.

The complicated functions which satellites are already performing illustrates this need. If the Rule of Law is to be effective in outer space, international regulations must be recognized and enforced dealing, for example, with frequencies permitted to be used by radio equipment on a satellite. If it is admitted that a satellite has the "nationality" of the launching State, then such State can be held responsible without question if the satellite uses unauthorized frequencies and thereby creates jamming or other types of international radio interference. This is but one example. Also reciprocally, when future control of outer space flight internationally has become effective, as it must, each State will have the right to protest against the interference with the flight of its satellites or other spacecraft, provided they are following authorized and internationally agreed patterns.

In the absence of the application of the requirement of flight instrumentality nationality, chaos and conflict will be inevitable in outer space.

Conclusion

Four fundamental problems have been stated, and tentative answers suggested. First, that the boundaries of outer space must be fixed and that the important lower boundary should be at a point above the surface of the Earth where it is possible to put a satellite in orbit at least once round the Earth.

Second, that the legal status of outer space must be fixed and that this could best be done by accepting a status similar to that of the high seas, thus permitting its equal use by all and denying to any State the right to assert sovereignty over outer space or any celestial bodies therein.

Third, that the international law right of a State to take action for its self-protection and self-defence must be preserved and acknowledged so far as outer space is concerned, even though no state has a right to claim sovereignty therein.

Fourth, that the legal status of satellites and of other spacecraft in outer space must be determined, and that this status should be that of "nationality" of the launching State, or other agreed State, otherwise chaos will result.

It is respectfully suggested that these four fundamental questions of outer space law stated demand urgent international settlement. It is also suggested that the solutions here put forward, when taken together, would provide a reasonable and practical foundation for the future application of the Rule of Law in outer space.

To the Editor of *Spaceflight*.

You have asked whether the proposals which I made in my lecture at Leiden University cover two problems stated below:

First, as to observation satellites. If and when a convention is adopted to govern the use of outerspace, this problem must be separately settled. It is not a new question. An aircraft flying over the high seas beyond the limit of territorial waters can "observe" by photography or otherwise, geographic conditions on a foreign shore and further inland. In my reference to adapting the quoted definition of the status of the high seas to the future status of outer space, I was fully aware that in the last phrase of Storey's definition, he stated that a ship pursuing its business on the high seas was, "bound to pursue it in such a manner as not to violate the rights of others." In my judgement, the same rule now applies to the flight of aircraft above the high seas beyond territorial waters. If it is now lawful for such aircraft to observe foreign shores, it should be lawful to make similar observations from outer space if outer space is to have the status of the high seas. As I stated above, I have no doubt that these questions must and will be settled when a complete international convention is drafted dealing with the use of outer space. In my lecture at Leiden, I suggested only the two basic clauses, but certainly such a convention will deal carefully with categories of permitted use of outer space by satellites and spacecraft. The

whole question of whether such use should be "non-aggressive," or "peaceful," or "non-military" will require international definition. May I also suggest that if the use of observation satellites and spacecraft constitutes "aggression," then my proposal that each State must preserve its rights of self-protection and self-defence would apply.

Secondly, as to "the status of an orbital boost-glider which, initially, performs as a satellite and thereafter, in coming out of orbit, requires considerable "airspace" in order to accomplish its drag-braking manœuvre and return to home base." My personal view has long been that the airspace of the Chicago Convention extends upward only through the areas where normal types of aircraft can be operated. If that is true, an intermediate area exists between this "airspace" and "outer space" as defined in my Leiden lecture. In a 1956 address before the American Society of International Law, I suggested that this intermediate area should, *by a new agreement*, be considered under sovereignty of the State below, subject, however, to "a right of transit through this zone for all non-military flight instrumentalities when ascending or descending." This, or some other solution, as to the status of the intermediate zone can only be settled by international means. However, unless the Chicago Convention is amended, the orbital boost-glider will definitely violate the sovereignty of States below if its glide-path includes any part of the limited Chicago Convention airspace. In suggesting the outer space definition at Leiden, you will note that I was careful not to state that all areas between such outer space boundary and the Earth's surface were now part of the territory of the subjacent State.

Princeton, N.J., U.S.A.
29 December, 1960.

JOHN COBB COOPER.

Reconnaissance Satellites*

By G. P. COATES†

Introduction

Reconnaissance is the examination of an area at a specific time for the purpose of obtaining information regarding the area and as such may form part of a more complete survey. It has military and civil applications and both will be dealt with.

Visual methods may be used for reconnaissance but more usually data are recorded by instruments which may or may not produce images in the process. Magnetometric, electromagnetic and temperature measurements are obtained by non-image forming methods, but these will not be dealt with further in this article. Instead we shall restrict ourselves to an investigation of the image-forming processes and their possible achievements when used in a satellite.

A new technology will continue to develop only if it can achieve a given result which is impossible, more difficult, more expensive or slower by any other method. Space technology is no exception and there are several scientific investigations which can only be performed by satellites. For other applications satellites must use to advantage their peculiar environment to justify their selection for the task. Satellites for survey and reconnaissance must be compared with aircraft, and will find their justification only where their superior height and speed or the absence of vibration are predominant requirements. Aircraft can quickly obtain photographic and other data from quite large areas and much more cheaply than would be possible using satellite vehicles. There are some reconnaissance tasks, however, for which only satellites can be used, *e.g.*, large, scale cloud cover investigations and military reconnaissance. For the former task satellites in low orbits are admirably suited; for the latter the highest flying operational aircraft are inadequate, as the Russians claim to have demonstrated by shooting down the American U-2 aircraft on 1 May, 1960.

It will be assumed that the ratio between the lowest perigee height of a satellite and the ceiling of the highest flying aircraft is at least five. Any advantages of increased height must be weighed against the loss of detail in the final result when the height is not dictated by other considerations, as it is in the case of military reconnaissance.

Orbits

The orbits of reconnaissance satellites determine the projected paths traced out by the satellites over the surface of the Earth, and these paths must clearly be close together or even over-lapping if the possibility of missing what may be important detail is to be avoided. However, the rotation of the Earth makes rapid coverage of a large area in acceptable detail very difficult. For instance a satellite on a polar circular orbit at a height of about 100 miles would cross the equator at points nearly 1500 miles apart on consecutive revolutions. Although this distance is smaller at higher latitudes it is clear that up to latitudes of practical interest the distance is appreciable. The fact that it would also have crossed the equator approximately 180° longitude and half a period away is not very important since observations would be made only over a short length of the orbit path. In the case of elliptic orbits this would, of course, be through perigee. Thus the Earth's rotation dictates considerable spacing of the satellite tracks across the Earth, and if the survey area is large the number of

* *A lecture presented before a meeting of the Yorkshire Branch of the B.I.S. in Leeds, 26 Nov., 1960.*

† *Astronautics Section, Advanced Projects Group, Hawker Siddeley Aviation, Ltd.*

tracks across this area to complete the coverage will also be large. The real criterion is the relationship between the period of the satellite and the period of the Earth's rotation. Not only must the satellite complete a non-integral number of orbits per day but the fractional part must repeat in such a way as not to sum to an integer during the lifetime of the satellite, in order to avoid passing over the same track more than once. This implies the use of an irrational number of orbits per day of the satellite.

The types of orbits most suitable for observation satellites are elliptic orbits with perigee heights fixed by considerations of atmospheric retardation and its effects on satellite lifetime on the one hand, and the height to give adequate resolution and coverage on the other. Apogee heights would be fixed by considerations of the time required for satellite interrogation and also from considerations of the effects of orbital period on the time for coverage of the area to be surveyed. Satellite interrogation time is important since this dictates the transmission power requirements. The lower the rate at which a given amount of information is transmitted the lower the power required. The receiving station would normally be under apogee.

Regarding orbital inclination, polar orbits are the only ones capable of giving complete coverage of the Earth's surface. Those with inclinations down to about 75° or even 70° to the equatorial plane would probably be sufficient to cover most cases of military interest.

Perturbations due to Earth's oblateness would cause motions superimposed on the basic elliptical motion and the effect of these would be to cause drifts in both latitude and longitude of the perigee and apogee positions. These effects would influence the useful life of a satellite but in the case of the photographic satellite would probably not be too important, since in this case the lifetime would be set by other factors and would normally be too short to be much affected by perturbations.

The launch of reconnaissance satellites into suitable orbits would be effected by launching at perigee with the velocity required to establish the design orbit. In cases where the launch site is situated such that this simple form of launch cannot be employed, *e.g.*, the military application, the satellite could be launched into circular orbit of radius equal to perigee radius and additional thrust applied to accelerate the vehicle to the required elliptic perigee speed during the first run over the subject area.

Possible Systems

The acquisition of data by the satellite will be referred to as the survey or observation process, and the extraction of information from the satellite as the interrogation process.

Photography, television and radar have special advantages as observation processes, while interrogation may be by film scanning with telemetry, film recovery, television or telemetry. Not all combinations of observation and interrogation processes are possible, but each possible combination together with the intermediate process of information storage, *e.g.*, on magnetic tape, must be considered as a complete system.

Photographic Observation

The photographic observation process is the one likely to yield results giving the highest resolution, *i.e.*, showing the most detail, and is therefore perhaps the strongest contender as the type for military use; it will therefore be considered in some detail as an example. In common with television it suffers from the disadvantage of requiring clear weather and daylight for its use. Photographic satellites would necessarily be rather heavy if they were required to give the highest resolutions available.

Photographic resolution is contributed to by many factors. The ratio of the lens focal length to the distance of the lens from the subject determines the scale of the image; and the longer the lens focal length the smaller its angle of view. The maximum film size is required in order to permit the extraction of the maximum of information from the film. Also the physical length of the lens unit would increase with increase of focal length. Therefore the weight of the camera would increase rapidly with increase of film size. These considerations limit the film size and hence the image size and it is necessary to consider the amount of information that can be extracted from this, *i.e.*, to consider the overall resolution of the image and the principal factors affecting it. These are the lens, the film itself and the conditions of operation of the camera.

The amount of detail which can be transmitted through a lens of given diameter is fundamentally limited by the wavelength of the light used, the detail being less the longer the wavelength. However, the practical limits of the lens restrict its performance more

Checking the alignment of the wide-angle TV-camera in the Tiros II meteorological satellite.

Radio Corporation of America

severely, even if only the longer wavelengths are considered. Both theoretical and practical limitations amount to the rendering by the lens of each point of light not as a corresponding point in the image but as a slightly blurred area, and the dimensions of this area determine the resolving power of the lens.

Even so the resolving power of the lens is normally greater than that of the film and whereas a good lens, particularly one of small aperture, may produce an image in which details down to about 1/4000 in. can be distinguished, this resolution is lessened to about 1/1000 in. when the lens is used in conjunction with even the most suitable film. The reason for this is that the image on a film consists not of continuous gradations but of tiny particles and these are not only of finite size, they are also irregular in size, shape and distribution throughout the film. It is clearly not possible to distinguish between objects producing images on the film smaller than these silver grains.

Unfortunately, the faster the film, *i.e.*, the greater its rate of reaction to light, the larger are the grains of the image, and hence the lower the resolution. Thus a high film speed, *i.e.*, a fast emulsion, could offset many of the difficulties of the operation of a camera in a satellite, but only by incurring penalties in resolution.

The operation of the camera, or more particularly the conditions of its operation, usually affect the overall resolution. For instance the vibration of the camera during the exposure interval may well cause blurring, which particularly applies to cameras carried in aircraft. Such vibrations would not normally be present in a satellite, but an effect which is exaggerated in the case of the satellite relative to the aircraft is that of movement of the vehicle itself. A reconnaissance satellite at a height of 100 miles would move relative to the ground at rather less than 5 miles/sec. Such a relative velocity would require very high shutter speeds in order to prevent considerable blurring of the image due to the distance moved during the exposure interval if the camera were stabilized vertically. Alternatively the camera (or the whole satellite) could be rotated so that it pointed at the subject area during exposure. Objects out of the plane of the subject area would be blurred by parallax movement, but in the case of even the tallest buildings and structures the effect would not be very important, nor would the real motion of clouds due to winds.

Consecutive frames can show adjacent areas below the satellite, because the dimension of this area will generally be greater than the distance moved through by the satellite during exposure. It will thus be possible to arrange for almost any degree of overlap that may be required.

Satellite to ground photography suffers loss of resolution owing to atmospheric scattering of light, chiefly by the water vapour and dust particles in the lower atmosphere. However, other glow effects may be unimportant, *e.g.*, noctilucent cloud and auroral phenomena.

Before leaving the subject of resolution mention should be made of contrast, which relates to the relative brightness of adjacent areas of an image. It is important here because a reduction of contrast, other things being equal, causes a corresponding decrease of resolution. Black objects against a white ground, or vice versa, are easily distinguishable, but pale objects would have to be much larger than black ones before becoming discernible against a white background. On the other hand an object narrower than the average resolution limit may be visible, if it is in high contrast to the background and many times longer than the resolution limit.

With this exception, these effects reduce the best overall resolution obtainable in a practical case to about 1/500 in. or more.

Capability of an Existing Camera

In order to get some idea of what might at present be achieved by a photographic reconnaissance satellite it is instructive to consider an existing camera as an example and to see what this is capable of on the basis of the above discussion.

Let us consider the long-range aerial reconnaissance camera. This is a film camera with a frame size of 9 in. × 9 in., a lens of 48 in. focal length and a focal plane shutter. The camera is about 5 ft. long and would weigh approx. 150 lb. From what has been said earlier the 48 in. lens will have a viewing angle of about 11°. Therefore from a height of 100 miles the area of ground covered by the lens will be about 19 miles square (see Fig. 1). Using our figure of 1/500 in. for resolution this camera using suitable film in the best conditions would permit minimum detail of about 25 ft. diameter to be distinguished, and so generally speaking objects smaller than the largest motor vehicles and river barges would not be distinguishable. A satellite incorporating such a camera would probably weigh about 800 lb. While a resolution of about 25 ft. would more than suffice for all

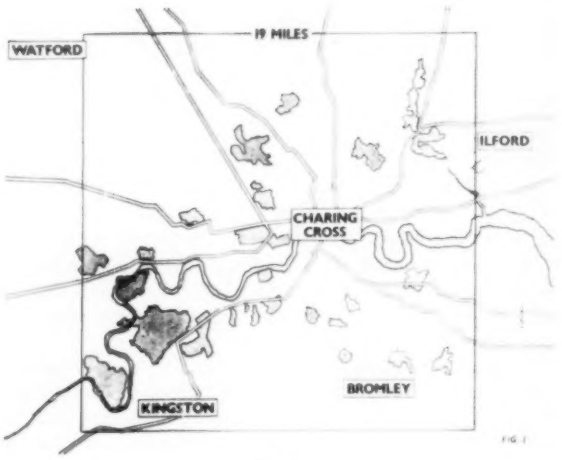

FIG. 1.

civil and most military requirements, and a satellite weighing 800 lb. would not be difficult to put into the low orbit required, the development of the required attitude stabilization system would probably take several years. Lenses of focal length greater than 48 in. have been tried for aerial reconnaissance but difficulties of overcoming distortions in use have been met. In satellite use the question of lens distortion could become acute unless the lens were protected from rapid and uneven temperature changes due to the relative motion of the Sun. This is especially true of the longer focal length lenses where the physical length may be such that the lens mount protrudes from the main body structure of the satellite.

Interrogation of Photographic Satellite

Two interrogation processes are feasible with a photographic system. The processed film may be scanned and the results telemetered to the ground station, or some or all of the processed film may be recovered. Since some of the resolution of the film image would be lost by scanning and transmission, the film recovery scheme would probably provide the highest resolution in the final pictures.

The "flying spot scanner" is the system most likely to be developed. The image on the film frame is delineated on a photoelectric cell array by transmission of a narrow pencil of light through the film. The electric signals from the cells would then be transmitted immediately or stored on magnetic tape. The Soviet Lunik III vehicle, which photographed the far side of the Moon, is alleged to have used film processing, 1000-line scan and telemetry.

Film recovery would be a more ambitious project, since the satellite would have to exhaust its film supply and then re-enter the atmosphere for recovery as a unit. Otherwise a number of capsules would be carried, when selected film enclosed in a capsule would be separated from the satellite and would descend on a pre-determined trajectory for recovery on land or at sea. Each capsule would have to carry a re-entry head, retro-rocket and a small radio transmitter to give out location signals, and would therefore weigh 100–150 lb. To justify these complications, a satellite would have to carry at least six capsules, and so the satellite would weigh at least $\frac{3}{4}$ ton.

The package recovery system is best suited for use in conjunction with a film-scanning system so that the entire sequence of relatively low resolution transmitted pictures could be appraised, and any film considered important enough packaged for recovery and further scrutiny in its high resolution condition.

External Limitations on Photographic System

The photographic system of observation would have limitations other than those inherent in the system. The method could only be used if the target area were sunlit and not obscured by cloud. It has already been indicated that the useful life of this type of satellite would depend largely on the amount of film carried; it is therefore necessary to use the film only when optimum conditions prevail.

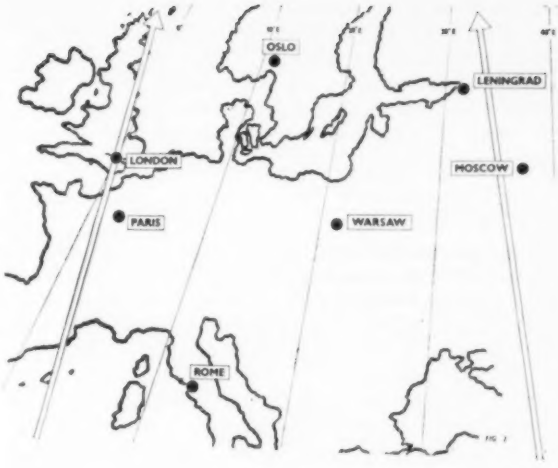

FIG. 2.

In this respect it should be possible to develop a photoelectric comparison device to determine if an area is clear, snow-covered, obscured by cloud or shadowed from the Sun and to allow camera operation only in favourable conditions.

Summarizing the remarks concerning the coverage by a photographic reconnaissance satellite, we see that the mapping of a large area of the Earth's surface with high resolution photographs would be a considerable undertaking, feasible only with the development of many new techniques. Either many satellites, or a very long time would be required to cover an area using the very narrow, widely-spaced strips resulting from the requirement for high resolution and from the rotation of the Earth. Lenses of different or variable focal length could be used in the same satellite to give wide coverage or high resolution as required.

Television System

The use of a television system for pictorial survey of the Earth's surface or of cloud distribution has the advantage that the results can be transmitted from the camera system, if a receiving or relay station is fairly close to the survey area, and if sufficient power is available. The system can be used for military and meteorological purposes in the same circumstances as a photographic system.

However, the resolution of the final pictures is not likely to approach that possible with a photographic system, for, while quite high resolutions are obtainable in the actual television process, much of this would be lost in background noise during transmission.

A television system is being used in the United States "Tiros 1" satellite which has taken many Earth's surface

and cloud cover photographs from a height of about 450 miles in a near-circular orbit. The pictures were taken by two cameras, one with a wide angle lens taking an area 800 miles square, the other an area only 30 miles square. The images, only ½ in. square, were scanned by 500 lines. The pictures were then stored on magnetic tape for later transmission.

Radar System

A radar reconnaissance satellite could take pictures at night or through cloud and has therefore a great advantage over the photographic or television system. However the resolution obtainable with radar would be relatively very poor. There are considerable difficulties also in other respects.

The smallest beam angle attainable is about 0·1°, this represents about 900 ft. at a height of 100 miles. This order of resolution is useless for most purposes. Coupled with this, such a beam width would require an aerial of about 70 ft. diameter if used with a frequency of 10,000 Mc/s., while higher frequencies would involve losses due to absorption by water in the atmosphere. For some meteorological applications this loss could, of course, be measured and form the raw data permitting higher frequencies and smaller aerials to be used.

A radar satellite could also be used to detect enemy radar signals. This would consist of a receiver with frequency scan and a means of pin-pointing the signal source.

Ground Equipment

The ground equipment necessary for a reconnaissance satellite system depends almost entirely upon the interrogation method employed. Data transmission by radio would require suitable dish antennae and associated equipment to be set up in suitable reception areas. For the order of transmitted power available from solar cell power units, the ground receiving aerials would be several tens of feet in diameter. For military uses these reception centres might be mobile or, if static, duplicated in case one station were put out of action.

Film recovery would require elaborate arrangement not only for location of the capsule, but also for its transport to the analysis centre which may not be in the recovery area. Ships, aircraft and land vehicles might all be required. Re-entry trajectories of high accuracy and reliability would have to be used. For military applications particularly, speedy location of the capsule is essential, any delay might render the information valueless. Further, flexibility of the recovery arrangements would be essential.

Future Possibilities

Concluding these brief remarks about reconnaissance satellites, two broader aspects of their use will be mentioned. The first is the possible use of the Moon as a base for a surveillance system. The advantage of the Moon over the artificial satellite is that it provides the opportunity of setting up far more elaborate and powerful equipment, which might make up for the many problems of increased distance. This inspection of the Earth might be regarded as one aspect of the obviously advantageous use of the Moon as an astronomical observatory.

The other use to which reconnaissance satellites could be put is the exploratory survey of celestial bodies. Satellites put into orbits round these bodies could obtain much information, *e.g.*, photographic and spectroscopic, etc., concerning the surface and any atmosphere present. Such information would not only be invaluable for scientific purposes but would be essential to a programme of investigation of a planet or other body prior to unmanned, and eventually manned vehicles being sent there from the Earth. Such satellites are not technically practicable at present. No vehicle has yet been put into orbit round even our nearest neighbour, the Moon, though one attempt has been made and another is due in mid-December, 1960.* Even when such orbits can be established, there remain the problems of sending sufficiently massive payloads to observe and record surface conditions, of operating the vehicle by command, of extracting data in usable form from the satellite and possibly of firing rockets to initiate a return to Earth. In order to evolve a vehicle with these capabilities considerable development is clearly necessary.

* *This, too, was frustrated because of a failure in the Atlas-Able launching rocket.*

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Reviews

"The Rocket Handbook for Amateurs" (an illustrated guide to the safe construction, testing, and launching of model rockets). Edited by Lt.-Col. Charles M. Parkin, Jr. John Day, New York. 1959. 306 pp. $5·95.

In the United States there are some 18,000 Science Clubs whose members are teen-age embryo scientists. Many of these youngsters, with or without adult guidance, embark on construction and launching of small rockets, often with disastrous results. The number of accidents is high enough to cause the American Rocket Society great concern, and the Society is planning an education programme to give young enthusiasts a sound training in elementary rocketry and astronautics. The Editor of the book under review clearly had the same idea but unfortunately it has not been well executed.

The book begins well by stressing the need for experiments to be carried out by properly-organized groups and not by individuals. Chapters on elementary orbital mechanics and space biology whet the reader's appetite, and his enthusiasm is kept within bounds by a chapter of safety rules which are sound if somewhat disjointed. Indeed, if all these rules were strictly observed the amateur would run little risk. The book then embarks on rocket technology, starting with descriptions of solid and liquid propellent rockets. The chapter on solid propellents is excellent, and it is a pity that this standard could not have been maintained. In fact the standard drops rapidly after this and, in spite of one or two valiant attempts, never really recovers.

The section on design, in the words of its author "contains a few heavy mathematical formulas," and he encourages the reader to try to understand them by substituting figures into them from the text. It is therefore particularly unfortunate that this section should contain a fair number of errors, since the student's confusion will thereby be worse confounded. Errors are avoided by the author of the next chapter (on pumps), but the reviewer feels that he lacks imagination. For example, eight pages of curves are included that would be of great value to professional pump designers, but the smallest pump to which they apply delivers about 8 lb./sec. Compare this with the pumps described in the notebooks of that master experimenter, Goddard, which delivered about 2 lb./sec. of liquid oxygen. Goddard, too, had the immense personal satisfaction of making most of his own parts, and surely this is the proper way to train young engineers; not, as is suggested here, merely to design a pump and submit it to professionals for cost estimation, manufacture, and testing.

A chapter on turbines contains a few slips but is generally good; the following one on cryogenics is really more than the amateur wants or needs to know. The section on instrumentation, like the earlier one on solid rockets, strikes just the right note. The book ends with a chapter contributed by the editor on "How to Build, Test, and Launch a Model Rocket"; it contains no references to lessons learned in earlier chapters and occasionally gives one a feeling that the writer had not read them.

This book contains evidence of careless editing, particularly in the section on nozzle design and later when expositions of elementary thermodynamics in adjacent chapters employ different symbols for the same quantities. One has the impression that the book was got out in a hurry to catch the market. There is undoubtedly a great need for a book of this kind, but unfortunately this one does not satisfy it.

"The Moon." By Zdenek Kopal. Chapman and Hall, London. 1960. 131 pp., 15 plates and 11 figures. 25s.

The statement on the dust-jacket that "This book describes in simple language our present store of knowledge concerning the physical properties and conditions prevailing on the Moon, . . ." is a fair indication of its purpose and scope.

After a short introductory chapter there follow eighteen pages of facts and figures relating to the Moon. These are followed by chapters dealing with different types of lunar features and their possible origins, the nature of the radiations falling on the Moon and their interpretation, the origin and composition of the dust which it now seems certain covers a large part of the surface, evidence for changes having actually taken place on the Moon within the history of telescopic astronomy, and some thoughts on problems that will arise when the first men reach the Moon.

Since there has been so much argument concerning the origin of the principal lunar features it is refreshing to find that the layman will not be misled into thinking that these are finally settled. Here both volcanic and meteoric hypotheses are given a fresh hearing. Of special interest is the comparison of the effects on colliding with the Moon of an asteroid and a cometary nucleus.

There are diagrams of the orbit of the Russian probe which successfully photographed the far side of the Moon, and one of the now famous photographs appears as one of the plates. Kozyrev's spectrographic observation of what is believed to be some kind of emission of gas from the Alphonsus region is described and well illustrated. It is charactristic of this book that Professor Kopal mentions Kuiper's objections to Kozyrev's interpretation of the spectra.

The excellent plates include several taken at the Pic du Midi Observatory and these are a welcome addition to the beautiful but now familiar pictures taken with the larger telescopes on the North American continent.

The author has produced a very readable and interesting book that will not only enable the layman to learn something of the Moon, but should also be useful to other non-specialist readers as a quick means of getting up to date. Lunar exploration has recently entered a new phase of quantitative research which may be expected to become more and more intense. It will not be Professor Kopal's fault if this volume requires considerable expansion and elaboration in only a few years' time.

M. J. HENDRIE.

"Introduction to Space." By Lee A. DuBridge, Columbia University Press. 1960. 93 pp.

One approaches a book of some 90 pages text, bearing the title "Introduction to Space," with some suspicions. The doubts gather on discovering that 24 of these pages are devoted to photographs and illustrations. These doubts are dispelled at the first reading and a good deal of admiration aroused.

Space is too large and nebulous for thorough treatment in 90 pages. The author has rightly selected topical and fundamental aspects for the four lectures—the book is the printed version of four inaugural lectures in the series honouring George B. Pegram of Columbia University. The first two deal with satellites and space-probes, in principle and practice. They bear the headings: "Attaining a Space Orbit" and "The Space Laboratory." Inevitably these have a personal bias and this adds liveliness. The second two chapters deal with astronomical space and are entitled: "The Solar System" and "The Universe." Once again doubts are raised. The Universe in twenty pages? Yet these pages are challenging ones and it is the challenges to astrophysics that are successfully conveyed. Not the *whole* of astrophysics; it is the sense of exploration that is caught. The occasional disconcerting exclamations are balanced by the numerous questions posed to science.

Who will benefit from this book? The author directs his remarks to "laymen and students." But various paragraphs in the last chapter would seem obscure to the layman. It is the student of allied disciplines and the scientifically-minded layman who should not miss the opportunity of reading these four addresses.

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Reviews

"The Rocket Handbook for Amateurs" (an illustrated guide to the safe construction, testing, and launching of model rockets). Edited by Lt.-Col. Charles M. Parkin, Jr. John Day, New York. 1959. 306 pp. $5·95.

In the United States there are some 18,000 Science Clubs whose members are teen-age embryo scientists. Many of these youngsters, with or without adult guidance, embark on construction and launching of small rockets, often with disastrous results. The number of accidents is high enough to cause the American Rocket Society great concern, and the Society is planning an education programme to give young enthusiasts a sound training in elementary rocketry and astronautics. The Editor of the book under review clearly had the same idea but unfortunately it has not been well executed.

The book begins well by stressing the need for experiments to be carried out by properly-organized groups and not by individuals. Chapters on elementary orbital mechanics and space biology whet the reader's appetite, and his enthusiasm is kept within bounds by a chapter of safety rules which are sound if somewhat disjointed. Indeed, if all these rules were strictly observed the amateur would run little risk. The book then embarks on rocket technology, starting with descriptions of solid and liquid propellent rockets. The chapter on solid propellents is excellent, and it is a pity that this standard could not have been maintained. In fact the standard drops rapidly after this and, in spite of one or two valiant attempts, never really recovers.

The section on design, in the words of its author "contains a few heavy mathematical formulas," and he encourages the reader to try to understand them by substituting figures into them from the text. It is therefore particularly unfortunate that this section should contain a fair number of errors, since the student's confusion will thereby be worse confounded. Errors are avoided by the author of the next chapter (on pumps), but the reviewer feels that he lacks imagination. For example, eight pages of curves are included that would be of great value to professional pump designers, but the smallest pump to which they apply delivers about 8 lb./sec. Compare this with the pumps described in the notebooks of that master experimenter, Goddard, which delivered about 2 lb./sec. of liquid oxygen. Goddard, too, had the immense personal satisfaction of making most of his own parts, and surely this is the proper way to train young engineers; not, as is suggested here, merely to design a pump and submit it to professionals for cost estimation, manufacture, and testing.

A chapter on turbines contains a few slips but is generally good; the following one on cryogenics is really more than the amateur wants or needs to know. The section on instrumentation, like the earlier one on solid rockets, strikes just the right note. The book ends with a chapter contributed by the editor on "How to Build, Test, and Launch a Model Rocket"; it contains no references to lessons learned in earlier chapters and occasionally gives one a feeling that the writer had not read them.

This book contains evidence of careless editing, particularly in the section on nozzle design and later when expositions of elementary thermodynamics in adjacent chapters employ different symbols for the same quantities. One has the impression that the book was got out in a hurry to catch the market. There is undoubtedly a great need for a book of this kind, but unfortunately this one does not satisfy it.

"The Moon." By Zdenek Kopal. Chapman and Hall, London. 1960. 131 pp., 15 plates and 11 figures. 25s.

The statement on the dust-jacket that "This book describes in simple language our present store of knowledge concerning the physical properties and conditions prevailing on the Moon, . . ." is a fair indication of its purpose and scope.

After a short introductory chapter there follow eighteen pages of facts and figures relating to the Moon. These are followed by chapters dealing with different types of lunar features and their possible origins, the nature of the radiations falling on the Moon and their interpretation, the origin and composition of the dust which it now seems certain covers a large part of the surface, evidence for changes having actually taken place on the Moon within the history of telescopic astronomy, and some thoughts on problems that will arise when the first men reach the Moon.

Since there has been so much argument concerning the origin of the principal lunar features it is refreshing to find that the layman will not be misled into thinking that these are finally settled. Here both volcanic and meteoric hypotheses are given a fresh hearing. Of special interest is the comparison of the effects on colliding with the Moon of an asteroid and a cometary nucleus.

There are diagrams of the orbit of the Russian probe which successfully photographed the far side of the Moon, and one of the now famous photographs appears as one of the plates. Kozyrev's spectrographic observation of what is believed to be some kind of emission of gas from the Alphonsus region is described and well illustrated. It is charactristic of this book that Professor Kopal mentions Kuiper's objections to Kozyrev's interpretation of the spectra.

The excellent plates include several taken at the Pic du Midi Observatory and these are a welcome addition to the beautiful but now familiar pictures taken with the larger telescopes on the North American continent.

The author has produced a very readable and interesting book that will not only enable the layman to learn something of the Moon, but should also be useful to other non-specialist readers as a quick means of getting up to date. Lunar exploration has recently entered a new phase of quantitative research which may be expected to become more and more intense. It will not be Professor Kopal's fault if this volume requires considerable expansion and elaboration in only a few years' time.

M. J. HENDRIE.

"Introduction to Space." By Lee A. DuBridge, Columbia University Press. 1960. 93 pp.

One approaches a book of some 90 pages text, bearing the title "Introduction to Space," with some suspicions. The doubts gather on discovering that 24 of these pages are devoted to photographs and illustrations. These doubts are dispelled at the first reading and a good deal of admiration aroused.

Space is too large and nebulous for thorough treatment in 90 pages. The author has rightly selected topical and fundamental aspects for the four lectures—the book is the printed version of four inaugural lectures in the series honouring George B. Pegram of Columbia University. The first two deal with satellites and space-probes, in principle and practice. They bear the headings: "Attaining a Space Orbit" and "The Space Laboratory." Inevitably these have a personal bias and this adds liveliness. The second two chapters deal with astronomical space and are entitled: "The Solar System" and "The Universe." Once again doubts are raised. The Universe in twenty pages? Yet these pages are challenging ones and it is the challenges to astrophysics that are successfully conveyed. Not the *whole* of astrophysics; it is the sense of exploration that is caught. The occasional disconcerting exclamations are balanced by the numerous questions posed to science.

Who will benefit from this book? The author directs his remarks to "laymen and students." But various paragraphs in the last chapter would seem obscure to the layman. It is the student of allied disciplines and the scientifically-minded layman who should not miss the opportunity of reading these four addresses.

The author warns that the chapters may be over-simplified and this, naturally, is a very real danger. And apology is no justification. But the danger is avoided and the simplified statements convey the correct impression of the whole field. It is a difficult course to steer; a wrong impression may do more harm than one inaccurate fact. The author navigates skilfully.

The book is an attractively produced complement to other more comprehensive, more expensive treatises. It has neither misprints nor errors and has but one handicap—the unhappy title.

K. Fea.

"International Missile and Spacecraft Guide." By Frederick I. Ordway III and Ronald C. Wakeford. McGraw-Hill Publishing Company. 1960. 11¼ × 9 in. xviii + 403 pp. £9 14s.

Great developments have taken place in the field of missiles and spacecraft since the war and the annual cost of these programmes has reached astronomical proportions running into thousands of millions of pounds. This Guide has been compiled to describe the end-products of this vast development programme, and represents the first attempt to publish an illustrated survey of all missiles and spacecraft throughout the world, details of which have been released.

Although the erratic behaviour of rockets deterred military planners from using them until World War II, the literature concerning both pre-war and subsequent developments that has been produced has exceeded all expectations. Much of this literature now lies in comparative isolation and relative seclusion, the information it contains having a very restricted circulation in relation to the total quantity produced. The authors have collected together much of this information and, although unclassified information has been used in the compilation of this Guide, some of the details have only become unclassified whilst the book was being prepared. For reasons of security this Guide can never be complete, but it makes an extremely valuable contribution to astronautical literature by summarizing within one cover all the details of each missile or spacecraft described by thousands of scattered facts, published in Journals all over the world. Some of this information has been taken from military archives direct and has never been previously released to the Press. Details are also given about little-known missiles which never reached the manufacturing stage, or were later abandoned because their requirements changed. Obviously American missiles have received better treatment in this volume because more information was available to the authors than in the case of missiles manufactured in other countries.

The Guide is divided into two main parts: Part 1 deals with the background to missile and spacecraft progress; Part 2 describes current missiles. The first part contains a history of missile development arranged in chronological order from the year A.D. 1200 together with tables of important vehicle launchings. This is followed by an international survey of the different organizations of missile activities in the countries concerned. Certain early developments have been selected for inclusion in the Guide and these are presented under the following headings: surface-to-surface; surface-to-air; air-to-surface and air-to-air missiles, rocket-powered aircraft; sounding rockets; test missiles; drones; special vehicles; manned missiles and spacecraft. Projected space programmes are also described in Part 1. The second part of the Guide describes all current missiles, the information being presented in the same form of categorization as used in the first part. This is followed by a section devoted to new developments and, finally, information received too late for inclusion in the body of the work.

One cannot fail to be impressed by this book, if only to appreciate the mammoth task facing the authors of collecting and collating the information. The high standard of McGraw-Hill has been maintained in every way and the reproduction of copious half-tone and line drawings leaves little to be desired. The only comment the reviewer would wish to make is that the pages are not all consecutively numbered in the usual way, but employ an alphanumerical system for about half the book.

M. D. Hull.

FUNDAMENTAL TEXTS IN ASTRONOMY REPRINTED

Today's great advances in space research are based on foundations laid down more than 50 years ago. Seven basic works on general and astronomical dynamics which helped to establish the background for our present-day developments have just been reprinted by Dover Publications, Inc., who are to be congratulated not only in doing this but in making these classics available at moderate prices.

"An Introductory Treatise on Lunar Theory" by Ernest W. Brown (292 pp., $2·00) is a famous American mathematician's contribution to the three-body problem. The author examines the five approaches presented by Laplace, de Pontecouland Hansen, Delaunay and Hill.

H. C. Plummer's "An Introductory Treatise on Dynamical Astronomy" (339 pp., $2·35) is an extended treatment of almost every theoretical and general principle in the field of dynamical astronomy. It is a standard text of great scope and lucidity.

Every basic mathematical method of determining, correcting or reducing observations of fixed stars is set forth in Simon Newcomb's "A Compendium of Spherical Astronomy" (444 pp., $2·25). The author was the most distinguished American astronomer of his time.

One of today's leading astrophysicists investigates the theory of stellar dynamics in "Principles of Stellar Dynamics" (313 pp., $2·00); S. Chandrasekhar, who is Morton D. Hull Distinguished Service Professor at the University of Chicago, deals with the theory as a branch of classical dynamics.

Of interest to a somewhat wider circle of readers will be the two volumes of "A Manual of Spherical and Practical Astronomy" by William Chauvenet (Vol. 1, 708 pp.; Vol. 2, 631 pp.; $2·75 per volume). Volume I deals with the general problems of spherical astronomy with special applications to nautical astronomy. Volume 2 deals with the theory and use of astronomical instruments, telescopes, micrometers, chronometers, sextants, transit instruments, etc. It also contains an appendix on the method of least squares.

"The Dynamics of Rigid Bodies" by W. D. MacMillan (433 pp., $2.00) is the third and final volume of a series devoted to theoretical mechanics and provides a detailed and comprehensive treatment.

With the republication of the Elementary Part of "Dynamics of a System of Rigid Bodies" by E. J. Routh (478 pp., $2·35), the complete 2-volume set of this classic reference on general dynamics is now available, for Dover has already published the author's Advanced Part which continues the exposition through application of the calculus to dynamic studies.

A full list of volumes can be obtained from the publishers at 180, Varick Street, New York, 14, N.Y., U.S.A.

L. J. Carter.

Correspondence

SIR,—With regard to your editorial comments on Sputnik V in the October, 1960, issue of ***Spaceflight***, it is true that *Tass* reported that both the capsule and the spacecraft made a successful landing in Soviet territory. You may, however, be interested in the following extract from a German newspaper report under the date-line, Moscow, 4 Sept., 1960 (U.P.I.). The translation reads: "The Soviet rocket having carried the 'space-dogs' Strelka and Belka around the Earth has not landed on Earth again, but burned up in the atmosphere. *Izvestia* published last week-end that the capsule with the animals was catapulted out at a height of some 70 km. and returned to Earth. After that the spaceship burned up."

Muelheim/Rhur, RAINER BLUM.
Oberstr. 96,
Germany.

There seems to be some confusion here. Following the re-entry of the Soviet spaceship into the Earth's atmosphere, the carrier rocket remained in orbit for several weeks. The pressure cabin, containing the two dogs (illustrated in ***Spaceflight*** *Jan., 1961) was catapulted free of the spacecraft at a height of some 23,000 ft. Both components were stated to have landed safely. What was said, however, was that "After the ship had passed into its descent trajectory, the instrument compartment was separated from the cabin and burned up as it entered the dense layer of the atmosphere" (quotation from "Izvestia"). The jettisoned part of the payload probably included telemetering equipment which had already served its purpose in relaying scientific information from orbit. Its release from the spaceship prior to re-entry decreased the mass of the vehicle, thereby reducing the demands on braking and recovery devices.*

Component weights were as follows: pressurized space-cabin, 5500 lb. approx. (including escape capsule which is catapult-ejected through a manhole), and instrumented compartment, 3250 lb. approx.—ED.

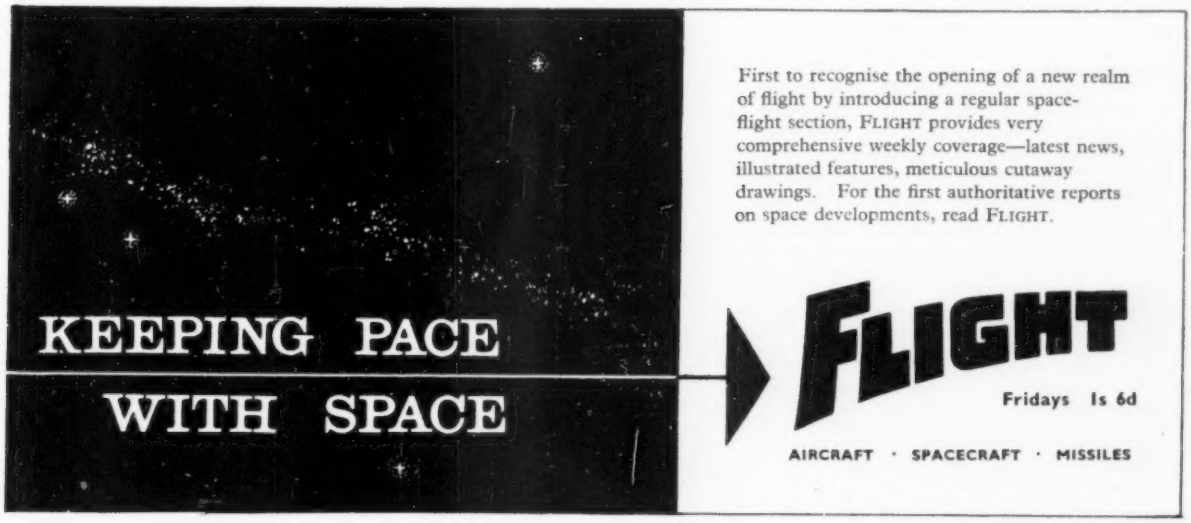
SIR,—In comment to Mr. Patrick Moore's review of "Astronomy" by T. G. Mehlin, I feel that I cannot agree that this is a wholly good book. It is true to day that photographic coverage is exhaustive and that no important graphs and diagrams or references have been omitted, but these are not the basic requirements of a good astronomical textbook. If less attention had been paid to design, to heavy glossy paper encrusted with a blue ink that can only be called gaudy and to stylish layout thus placing the book well out of financial reach (speaking as a student) and more to a logical, straightforward presentation in a good literary hand, I feel the book would have appealed more to the student and to the general reader. If these standards cannot be met, the book should not be attempted.

It is plain that the novice would soon become bogged-down with a style that is impregnated from the start with poorly explained terms and questionable scientific jargon. There can be no comparison with the masterpieces produced for a third of the cost by Sir James Jeans in the nineteen-thirties. Must one be reminded that scientific writing is not merely the stringing together of figures and facts with "and"s, "but"s and "if"s; the sole purpose of a textbook is to educate the reader, not to create the impression that the writer is some demi-god of science with all the information in the Universe at his finger-tips. The author must always spend a great deal of time in seeing that he has not only expressed himself clearly but with the minimum use of jargon and the maximum flexing of personality. A cold impersonal text is not what should be aimed at. May I plead on behalf of all students, that writers of texts make their books logically sound, literarily sound and *interesting*.

Yours, etc.,
R. R. AUSTIN.

SIR,—I was rather disappointed by Mr. Macvey's article[1] on Lunar Craters, since it seemed that he had omitted a full discussion of a number of points arising from the Meteoric and Plutonic theories and instead devoted an undue amount of space to the outdated—and never plausible—Volcanic Fountain theory.

In his discussion of the Meteoric theory Mr. Macvey raises a number of objections, none of which, however, is as conclusive as he would suggest. Undoubtedly the summit craters must be explained as being the result of volcanic action; but they are quite different in form from the ringwalls, so their origin may also be different. It is difficult to discuss Mr. Macvey's second objection—that the craters form chains containing members of different ages—as he does not explain what unequivocal criterion of age he is using. However this, and his third objection, that it is usually smaller craters which break into larger, are both statistical matters—in a scatter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of craters, one would expect some lines to be formed randomly, and from the very size difference, it is more likely that a small crater would break into a large one than that a large one would overlap a small one without completely obliterating it. In spite of the efforts of Firsoff[2] and others to construct "Lunar Grids" of crater-chains showing the lines of weakness in the Lunar crust produced by tidal action of the Earth, many "straight lines" consisting of only three (or sometimes only two!) craters have to be invoked; what is needed is a mathematical analysis of the arrangement of the craters to determine what are the chances against such an arrangement's being produced by a random process. Until such analysis has been completed, these objections to the Meteoric theory must be speculative only.

The Plutonic theory, in the form advocated by Mr. Macvey, is open to one of the main objections levelled at the Volcanic Fountain theory: why, in a several-stage or continuous process, do we not see more evidence of the successive stages? One would expect that many craters would have several concentric low walls produced by successive "bubbles" of rather different sizes; surely it is too much of a coincidence to suppose that the gas-pressure is always exactly the same in each "bubble" at a given site—although different at different sites—so as to produce craters of different sizes, but each with a single (if perhaps terraced) wall? These considerations make it more likely that any given crater was formed in a single-stage process: either a meteoric impact or a single plutonic dome. A further point in favour of the latter theory is the presence on the Moon of domes, which might be late examples of plutonic activity which solidified before "bursting" or collapsing.

In conclusion, I wonder whether the publication of articles like Mr. Macvey's serves any real purpose? The information contained in it could be found in any elementary book on selenology (*e.g.*, Firsoff,[2] Moore[3] and it is not even useful as a guide to the literature as Mr. Macvey fails to give references to the original publication of the work to which he refers.

Yours, etc.,

Hatch End, Middx. G. T. KINGSLEY.

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1. Macvey, *Spaceflight*, *III*, 1, 1961.
2. Firsoff, "Strange World of the Moon."
3. P. Moore, "Guide to the Moon."

Mr. Macvey replies:—

I would like to express my thanks to Mr. G. T. Kingsley for his interest and comments which, even though generally critical, are appreciated. Perhaps he may find the following few comments appropriate and of equal interest.

1. "Craters of the Moon" was meant to be a *general* article on the subject suitable for the interested layman among others. Consequently, in fairness, *all* theories must be dealt with—even the outmoded ones. At the same time one cannot wholly overlook the restrictions of journalistic space in expanding the more plausible ones.

2. Mr. Kingsley comments: "Undoubtedly the summit craters must be explained as being the result of volcanic action; but they are quite different in form from the ringwalls, so their origin may also be different." I wholly agree and this is precisely what I said!

3. He further comments: "From the size difference it is more likely that a small crater would break into a large one than that a large one would overlap a small one without completely obliterating it."

From a mathematical point of view there is something to be said for this, and I cannot express disagreement any more than I would like to come down categorically in favour. Nevertheless, there is a considerable body of opinion which strongly adheres to the facts as I presented them—*viz.*, that as the Moon aged the amount of igneous activity declined, resulting in the *older* craters being the *larger* with the smaller, newer, craters breaking into them."[2]

4. I am also inclined to endorse Mr. Kingsley's plea for a mathematical analysis of the arrangement of the craters. With regard to his remark, however, that until the completion of such an analysis the objections to the Meteoric theory can only be speculative, I feel that he is merely stating the obvious since, of course, all such objections in such a matter as this must by their very nature remain (perhaps forever) at least a trifle speculative.

5. Mr. Kingsley outlines several (and in my opinion) very valid points relating to the Plutonic theory. However, I can only re-iterate my own words on the subject as given in the original article. "The plutonic alternative may *not* be *wholly accurate* but *modifications* and *extensions* to it *may* well approximate rather closely to the truth."

6. With regard to Mr. Kingsley's viewpoint as to the value of such generalized articles, I feel obliged to take a more firm stand. I freely concede that all such information can be obtained from the accepted works on selenology. Nevertheless, ***Spaceflight*** is directed not only toward the professional worker in the field of astronautics and kindred sciences, but also to the interested layman who may not necessarily be prepared to delve into serious (or even elementary) astronomical literature. Hence I feel there is a need for general astronomical articles related to astronautics, interspersed with popular, current and accurate astronautical material. And should such general articles tempt the interested layman to seek out the fuller treatise then surely an even more useful purpose will have been achieved! Naturally, of course, this is a matter for the Editor and Editorial Board, since it concerns magazine policy and in fact it is probably rather unethical for a contributor to dwell upon such points. This particular contributor hopes the Editor will forgive him!

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1. P. Moore, "The Amateur Astronomer."
2. P. Moore., "Guide to the Moon."

The Washington Congress

The American Rocket Society have announced that the XIIth Congress of the International Astronautical Federation will be held in Washington, D.C., from 2-7 October, 1961. It will be immediately followed, in New York, by the A.R.S. "Space Flight Report to the Nation," from 9-14 October.

Both occasions should be memorable in their own right. In addition to plenary sessions of the I.A.F. Council, the Congress will include the usual programme of lectures by international authorities, and separate meetings will be held both of the Academy of Astronautics and the Institute of Space Law.

The A.R.S. "Space Flight Report to the Nation" will be the largest function of its kind ever held in the field of astronautics. Exhibits from more than 300 American companies will occupy some 250,000 sq. ft. of the New York Coliseum, and six technical sessions will be held concurrently.

In order to assist B.I.S. members to attend the I.A.F. Congress, and at least a part of the second meeting, the Society is hoping to organise a charter flight from London. Members who may be interested in participating are asked to notify the Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.

Superior Galactic Communities

By MICHAEL H. BRIGGS,* M.Sc., F.R.A.S.

Radio Communications

Two professors of Physics at Cornell University, G. Cocconi and P. Morrison, have recently published a paper[1] suggesting that if, as seems very likely, alien intelligent beings exist on planets elsewhere in our galaxy of stars, then their scientific and technological achievements may be sufficient for them to be certain of the existence both of the Earth and of ourselves as an intelligent life-form. Granted these assumptions, what more likely than that these aliens will try to establish contact with us?

Cocconi and Morrison suggest that the most likely means of communication is by radio transmissions on a frequency of 1420 Mc./sec. This is the frequency of the 21-cm. line of interstellar hydrogen, which, being the commonest radio frequency in the universe, will probably be the first radio signal from space detected by intelligent beings on any planet in the universe.

Dr. Frank Drake of the U.S. National Radio Astronomy Centre in West Virginia, has undertaken[2] a programme of research with the new 85-ft. radio telescope at the Centre, fitted with specially constructed equipment, to search for these intelligently directed radio signals.† He is first examining two solar-type single stars, tau Ceti and epsilon Eridani; both are about 11 light years distant.

Drake hopes that artificial radio signals of 1420 Mc./sec. frequency can be distinguished from natural radio emissions by the features of the signal received. For example, if the artificial emission is coming from a planet, there should be appreciable Doppler shifts of short period in the transmitted frequency due to the rotation of the planet on its axis and around its parent star. Moreover, the artificial signal will probably have a narrow bandwidth, while natural signals have broad bandwidths. It also is presumed that the aliens will deliberately render the signal capable of detection as an artificial transmission by sending a "message" composed of some regularly repeated pattern of impulses.

Life in the Universe

The basic idea behind these developments is nothing new. People have been suggesting that intelligent beings exist on other planets for many years. But this is the first time (apart from an abortive attempt to communicate with Percival Lowell's hypothetical Martians by laying out a giant diagram of Pythagoras' Theorem in the Sahara Desert early in the century) that anyone has decided to make a determined effort to see if communication with alien intelligences is possible.

The reasons for the optimism behind the present work are not difficult to understand. In the first place the large sensitive radio instruments necessary for the work are now available. Secondly, although the mechanisms of the origin of planets and of life are still far from fully understood, there is every reason to believe that both are evolutionary processes that have occurred many times in our galaxy.[3] This is particularly so now that Professor Fred Hoyle has found evidence that our galaxy has existed for more than 10^{10} years,[4] while the age of Earth is only around 5×10^9 years. Man may be the youngest intelligent life-form in the galaxy.

This picture of the place of terrestrial life in the universe is quite different from that accepted only a decade or two ago, when the influence of the thought and writings of Sir Arthur Eddington and Sir James Jeans were current. Both believed that the Solar System and life on Earth were unique in the galaxy, possibly in the universe, and their beliefs have played a tremendous part in forming intelligent opinion on such matters in the English-speaking world.

Now we think that the Sun is probably a second generation star, possibly formed partly from the exploded debris of stars that were formed, evolved and died, thousands of million years before the Solar System originated. Planets bearing life may have arisen and alien civilizations and superior galactic communities been formed eons before our Earth existed.

Against this view is the possibility that first generation stars lacked the heavy elements necessary for terrestrial-type planets and for life as we know it. This is something that cannot yet be decided, but it scarcely affects the belief that much older, life-bearing, planets exist elsewhere in our galaxy.

Artificial Probes

Stimulated by the possibility that an interstellar contact with a superior galactic community may be imminent, a number of other scientists have published papers dealing with other aspects of the problem.

For example, Professor R. N. Bracewell of Stanford University has suggested[5] that aliens might well select other means of communication, rather than maintain for millenia the thousands of megawatt transmitters which would be needed to signal all possible life-bearing planetary systems in their vicinity. Bracewell proposes that a likely alternative is the launching of unmanned space probes to be directed by the aliens into orbit within the ecosphere (the zone of space around a star in which

* *Department of Chemistry, Victoria University of Wellington, New Zealand.*

† *This project was recently terminated, according to Dr. Otto Struve, director of the N.R.A.C., because the receiving equipment was not sufficiently sensitive. Ed.*

the temperature is conducive to the existence of life) of each of the systems. These probes could then either transmit signals of the type described above for detection by any intelligent life-form on a planet in the system, or could listen for artificial signals from nearby planets and, if any were detected, record and re-transmit the signals back to source. In this latter way there would be certainty that the contacting signal is of a wavelength and in a band capable of being received by the intelligent beings.

If this proposal is correct there may be a probe of this sort actually within the Solar System at the present time; presumably circling the Sun somewhere between the orbits of Venus and of Mars and broadcasting radio signals for our detection. Bracewell suggests that some radio signals reported in 1928[6] which had unexplained long echoes, might have been re-transmissions from this hypothetical probe. If he is right we presumably can expect more concrete contacts at any time.

Artificial Stellar Sources of Infra-red Radiation

A possible alternative way of recognizing the location of superior alien beings, other than by their transmission of artificial radio signals, has been proposed by Freeman J. Dyson of the Institute for Advanced Study at Princeton.[7] Arguing from expansions of population and of technological achievements, he suggests that to make adequate and efficient use of the radiation from their parent star, the aliens could undertake the ambitious project of dissembling and rearranging the matter of a major planet of their system into the form of a spherical shell around the star. The shell, which would have a diameter of around 400 millions miles, would be about 3 m. thick and would contain machinery to exploit the solar radiation falling on its inside surface.

From the outside the shell would give off no radiation in the shorter wavelengths, but would emit in the far infra-red around 10μ in wavelength. Dyson proposes that a search be made for dark objects of this sort—a project that appears well within the capabilities of existing astronomical techniques.

While one can agree that all intelligent life-forms will probably be afflicted by population problems of the type outlined by Malthus, it is pure speculation whether the construction of artificial stars of this type are within the scope of any life-form, no matter how advanced.

Conclusions

Unless we have made a lot of mistakes in recent scientific thinking, it is reasonable to believe that civilizations of intelligent beings, older and probably superior in technology to ourselves, exist on planetary systems in our galaxy.

Studies[8] of the distribution of stars within the galaxy indicate that some 80 to 90% are confined within a flattened sphere of major radius about 15,000 light years. Consequently, our Sun, which is about 27,000 light years from the galactic centre, is part of a small minority. Assuming that superior galactic communities are approximately evenly distributed in the galaxy, the great majority must be close to the galactic centre—few can be as far out as the Sun. Moreover, the average separation of stars at the galactic centre is about 1 light year, while in the region of the Sun it is slightly over 9 light years. It is obvious that the chances of the existence of a superior community near to the Solar System are very much less than the chances of a community nearer to the centre of the galaxy. Yet this must not deter us from making the greatest efforts to determine whether or not these hypothetical communities do really exist. The establishment of contact with such a community will obviously be of the greatest scientific and social importance.

So far we are only looking for artificial radio signals, but it has been suggested that we should also search for artificial probes within our System and for artificial sources of infra-red radiation. Both these projects should obviously be attempted, but perhaps we should also try the long-term experiment of beaming radio signals at the nearest accumulations of stars most likely to contain a superior community.

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2. F. D. Drake, *Sky and Telescope*, **19**, 140, 1960.
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Question and Answer

A satellite is injected into a 24 hr. west-east orbit which is inclined at 60° to the equator. To an observer on the Earth the satellite appears to track round a figure of eight. Why is this? Why does it not appear to move along a meridian from 60° N. to 60° S.?

A satellite travelling in any 24 hr. circular orbit moves round a figure eight track from the point of view of an observer on the Earth's surface, except in the limiting case of an orbit exactly in the equatorial plane. Consider the movement of the point vertically below the satellite. This

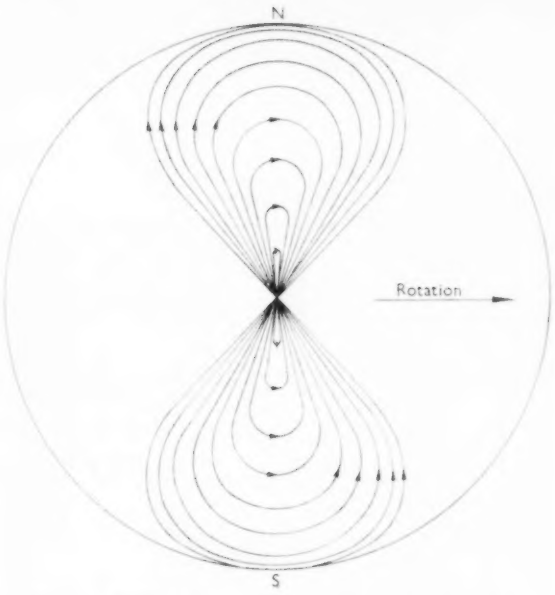


FIG. 25. Sub-satellite tracks for nine 24-hr. circular orbits at inclinations from 10° to 90°.

travels on a great circle path with a uniform speed of 1037 *m.p.h., the same speed as a "stationary" point on the equator has by virtue of the Earth's rotation. Thus when the satellite passes across the equator in either direction its equatorial velocity component is less than the rotational speed, and it appears to come from East of the true North or South. At the most northerly or southerly parts of its orbit the satellite moves faster than the Earth beneath it, so that it travels from West to East.*

The resultant figure eight tracks are shown for the nine orbits with inclinations varying in 10° *steps from* 10° to 90°. *The direction of motion is shown by the arrows, and the track can never be traced out in the opposite direction.*

Whilst real satellites could have their period adjusted to exactly 24 *hr., they are likely to move in more or less elliptical orbits. This leads to another kind of oscillation about the mean stationary point, for at perigee the motion will be retrograde, whilst at apogee it will be direct. Combining the two effects we see that "real"* 24 *hr. satellites will move in a distorted figure eight path, in which the cross-over point is not restricted to the equator.*

For a very detailed treatment of all these periodic or libratory orbits reference could be made to the book "Soviet Space Science," by Ari Shternfeld, available in an English translation published by Basic Books Inc., New York.—C. A. CROSS.

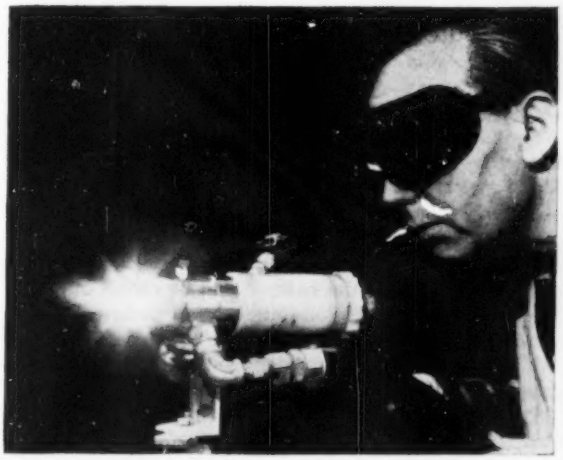
Electrical Rocket Propulsion

Three general types of electric propulsion systems for space applications are currently under investigation in various industrial and governmental research laboratories in the United States. These are: (1) the arc jet (or electro-thermal) rocket engine; (2) the ion rocket engine; and (3) the plasma or magnetohydrodynamic (MHD) rocket engine.

Simply stated, the *arc jet rocket* engine derives its thrust from gas (working fluid) heated by passing it through an electric arc. The heated gas expands supersonically through a rocket nozzle.

An *ion rocket* operates by acceleration of positively charged particles (ions) ejected rearward by an electrostatic field. (An ion is an atom from which an electron—negatively charged particle—has been removed. Since an atom is neutral in charge, the removal of an electron leaves the remaining particle positively charged.) In a *plasma or MHD rocket* engine, highly ionized gas (plasma) is accelerated by electromagnetic fields. Some system designs accelerate the plasma continuously, others in an intermittent or pulsed fashion. In *chemical rockets*, the source of energy is the combustion process of the propellants. In electric propulsion, electrical energy would be obtain from a power supply operated by solar or nuclear energy.

The arc jet rocket engine is currently the simplest and furthest developed of the different proposed electric propulsion devices. The working fluid is injected into the arc chamber, heated as it passes through the discharge, and is expanded through a conventional rocket nozzle.



Preliminary test of the Avco arc-jet engine prior to being placed in a vacuum chamber for a 47-hr. test run under simulated space conditions.

Avco Corporation

The convergent-divergent nozzle serves to convert the ohmic heating in the electric arc discharge into directed kinetic energy.

Generally speaking, arc jet engines operate in a specific impulse* range of 1000–1500 sec. compared to chemical rocket I*sp* of 250–300 sec. Ion rockets operate in the general range of 10,000 sec. upwards but produce much less thrust. It can be shown that for flights of lunar distance the ideal specific impulse range is less than 5000 sec. MHD rocket engines will operate in an I*sp* range of about 1500 sec. upwards.

The Avco arc jet recently tested for 47 hr. weighs only 3·5 lb. It consists of a tungsten composite cathode and liquid-cooled copper anode. It has used both helium and hydrogen as working fluids.

Average performance specifications are: thrust level, 0·50–1·0 lb.; specific impulse, 750–1500 sec.; power level, 25–35 kW.; and over-all efficiency (electric to kinetic), 35–75%.

** Specific impulse is defined as "lb. thrust" divided by "lb. per sec. mass flow" (F/W = lb./lb./sec.). The lb. units cancel out leaving specific impulse units in seconds.*

Missile "Drag" Balloon

Coated fabric balloons which inflate in one-tenth of a second have been developed for a high-altitude recovery system designed to control deceleration of re-entry vehicles. The spherical drag ballons will be used to prevent tumbling and to control the speed of instrumented nose cones, manned escape capsules and other orbital devices during re-entry into the Earth's atmosphere. A parachute is ejected at lower altitudes to complete the recovery.

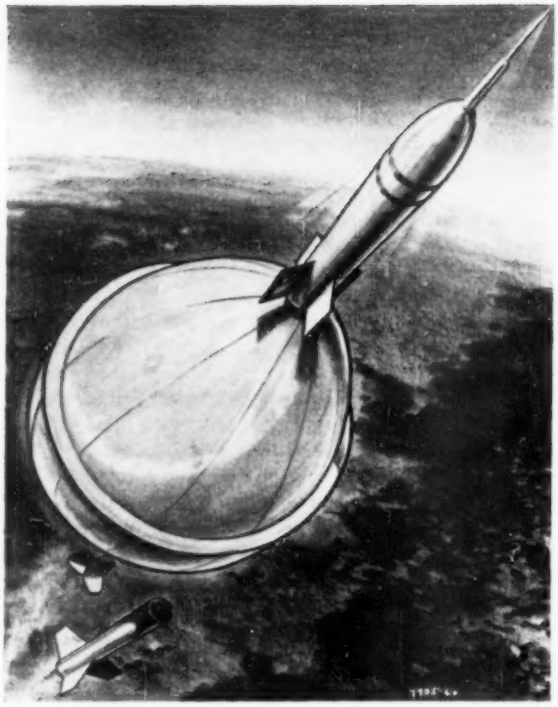
The balloon-parachute system was developed by Goodyear Aircraft Corporation for the United States Air Research and Development Command's Wright Air Development Division.

Specially modified Cree tests missiles are to evaluate the recovery system. One shot will seek a velocity of Mach 2 at an altitude of 150,000 ft. and a second firing of Mach 3 velocity will be made to 200,000 ft.

During tests, the 9-ft. diameter drag balloon will be deployed and inflated behind the missile. Once the missile is stabilized, the balloon will be reeled out until it reaches the flow region suitable for maximum drag. When speed has been sufficiently reduced, the parachute will be ejected at a lower altitude to complete the recovery.

During recent wind-tunnel tests of ¼-scale models at Langley Research Centre, Virginia and the Lewis Research Centre in Cleveland, Ohio, balloons were tested at simulated altitudes of 155,000 ft and speeds approaching Mach 3·5.

The tests, according to G.A.C. engineers, simulated actual ejection, inflation and deployment of the drag balloon configuration under high-speed flow conditions. The balloons proved to be perfectly stable bodies in subsonic, transonic and supersonic flow conditions.



Goodyear 9 ft. diameter coated fabric "Ballute" deployed for recovery of a test vehicle. *Goodyear Aircraft Corporation*

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THE BRITISH INTERPLANETARY SOCIETY

THE BRITISH INTERPLANETARY SOCIETY was founded in 1933 to promote the development of astronautics—interplanetary exploration and communication—by the study of rocket engineering, space medicine, astronomy, navigation, astrionics and other associated sciences. Its membership is international and includes most workers prominent in these fields.

The main work of the Society consists in the publication of two periodicals (free to all members); in the publication of books and monographs; and the organization of scientific and technical meetings. In addition to symposia and meetings at which original research papers are presented, lectures, exhibitions, visits to research establishments and film shows are held to explain to the lay public the progress that is being made in astronautics and the ultimate implications to human society of the crossing of space.

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The general requirements for Fellowship are any one of the following:

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(*c*) Considerable contributions to the development of astronautics.

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